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HAZARDOUS/TOXIC AIR POLLUTANT CONTROL TECHNOLOGY

A LITERATURE REVIEW

by

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16. ABSTRACT The report summarizes literature on hazardous/toxic air pollutant (HAP) sources and control techniques employed in their reduction and/or destruction. The information was abstracted from an extensive computerized and manual literature search and data base development study. The primary emphasis of the report is on HAP control technology. However, a brief summary of major source categories that emit HAPs is also included. About 70 hazardous/toxic compounds or groups of compounds are covered in this study; most are volatile organic compounds. In the HAP control technology data base, most of the information is for the Synthetic Organic Chemical Manufacturing Industry (SOCMI) source category. However, data are also available for the combustion, solvent use, and metal processing industries. The major add-on control techniques for volatile organic HAPs discussed in this report are combustion, absorption, adsorption, and condensation. Combustion techniques include thermal and catalytic incineration, flaring, and disposal of waste streams in boilers and process heaters. The add-on control devices identified in the literature for control of particulate HAP emissions are electrostatic precipitators, baghouses, wet scrubbers, and cyclones. A list of references identified during this study, along with abstracts of those references, is included.

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Toxicity	Stationary Sources	06T
Reviews	Hazardous Air Pollutants	05B
Organic Compounds		07C

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ABSTRACT

This report presents a summary of literature on hazardous/toxic air pollutant (HAP) sources and control techniques employed in their reduction and/or destruction. The information was abstracted from an extensive computerized and manual literature search and data base development study. The primary emphasis of the report is on HAP control technology. However, a brief summary of major source categories that emit HAP's is also included.

There are about 70 hazardous/toxic compounds or groups of compounds covered in this study with the majority being volatile organic compounds.

In the HAP control technology data base, a large proportion of the information is for the Synthetic Organic Chemical Manufacturing Industry (SOCMI) source category. However, data also are available for the combustion, solvent use, and metal processing industries.

The major add-on control techniques for volatile organic HAP's discussed in this report are combustion, absorption, adsorption, and condensation. Combustion techniques include thermal and catalytic incineration, flaring, and disposal of waste streams in boilers and process heaters. The add-on control devices identified in the literature for control of particulate HAP emissions are electrostatic precipitators, baghouses, wet scrubbers, and cyclones.

A listing of the references identified during this study along with abstracts of those references are included in the Bibliography section.

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SECTION 1

INTRODUCTION

The initial objective of this study was to compile, organize, and review scientific literature and Government publications relating to: (a) hazardous/toxic air pollutant (HAP) sources and (b) control techniques used in reducing and destroying HAP's. This objective was later narrowed and the study was focused on HAP control technology. Table 1-1 lists the HAP's for which controls have been identified in the literature search.

In this study, the term HAP's is used to designate noncriteria air pollutants that are, or have, the potential to be hazardous or toxic to humans. Since this definition is very broad and can encompass hundreds of specific compounds, a preliminary screening of the literature resulted in a very large number of references. Therefore, the Environmental Protection Agency's (EPA's) list of 37 potentially toxic substances was chosen as the basis for a compound-specific literature search. From this list (presented in Table 1-2), 14 compounds/groups that are not well characterized in the literature were selected for further study. A preliminary evaluation of the references in the data base indicated that much of the data and literature applies to control technology and covers several other pollutants in addition to the 14 indicated in Table 1-2. Following review of the classification of references by the Project Officer, a decision to focus on evaluation of control technology literature was made.

This document is not a definitive study on HAP emissions or control techniques but is an attempt to summarize the readily available literature on HAP emissions and controls for the compounds studied. The document should serve as an aid in identifying primary references for HAP studies. It can also be used to indicate significant gaps in the existing HAP literature. Since this study was a quick look at the existing HAP literature, all of the references in the literature are not covered. A

TABLE 1-1. LIST OF HAP's INCLUDED IN THIS STUDY

Pollutant	CAS No.
Acetaldehyde	75-07-0
Acetic acid	64-19-7
Acetic anhydride	108-24-7
Acetone	67-64-1
Acrolein	107-02-8
Acrylic acid	79-10-7
Acrylonitrile	107-13-1
Adipic acid	124-04-9
Allyl alcohol	107-18-6
Allyl chloride	107-05-1
Aniline	62-53-3
Benzene	71-43-2
Benzyl chloride[a]	100-44-7
1,3 Butadiene	106-99-0
Cadmium	7440-43-9
Caprolactam	105-60-2
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroform	67-66-3
Chloroprene	126-99-8
Chromium	7440-47-3
Coke oven emissions	-
Copper	7440-50-8
m-Cresol	108-39-4
o-Cresol	95-48-7
p-Cresol	106-44-5
Cumene	98-82-8
Cyclohexane	110-82-7
Cyclohexanol	108-93-0
Cyclohexanone	108-94-1
Diethanolamine	111-42-2
Dimethyl nitrosamine[a]	62-75-9
Dimethyl terephthalate	62-75-9
Epichlorohydrin	106-89-8
Ethylbenzene	100-41-4
Ethylene	74-85-1
Ethylene dichloride	107-06-2
Ethylene glycol	107-21-1
Ethylene oxide	75-21-8
Fluorocarbons	-
Formaldehyde	50-00-0

TABLE I-1. LIST OF CHEMICALS INCLUDED IN THIS STUDY (CONCLUDED)

Compound	CAS No.
Hexachlorocyclopentadiene	77-47-4
Maleic anhydride	108-31-6
Methanol	67-56-1
Methyl chloride	74-87-3
Methyl chloroform	71-55-6
Methyl ethyl ketone	78-93-3
Methyl methacrylate	80-62-6
Methylene chloride	75-09-2
Nitrobenzene	98-95-3
Nitrosomorpholine	110-91-8
Perchloroethylene	127-18-4
Penol	108-95-2
Phosgene	75-44-5
Phthalic anhydride	85-44-9
Polychlorinated biphenyls	1336-36-3
Propylene oxide	75-56-9
Styrene	100-42-5
Terephthalic acid	100-21-0
Toluene	108-88-3
Toluene disocyanate	91-08-7
Trichloroethylene	79-01-6
Trichlorofluoromethane	75-69-4
Trichlorotrifluoroethane	76-13-1
Vinyl acetate	108-05-4
Vinyl chloride	75-01-4
Vinylidene chloride	75-35-4
m-Xylene	108-38-3
o-Xylene	95-47-6
p-Xylene	106-42-3
Zinc	7440-66-6

[a] No specific control information was identified for this compound.

TABLE 1-2. EPA'S LIST OF 37 POTENTIALLY TOXIC SUBSTANCES

Acetaldehyde
Acrolein[a]
Acrylonitrile
Allyl Chloride
Benzyl Chloride[a]
Beryllium
Cadmium
Carbon Tetrachloride
Chlorobenzene[a]
Chloroform
Chloroprene[a]
Coke Oven Emissions[a]
o-,m-, p-Cresol[a]
p-Dichlorobenzene
Dimethyl Nitrosamine[a]
Dioxin
Epichlorohydrin
Ethylene Dichloride
Ethylene oxide

Formaldehyde
Hexachlorocylopentadiene[a]
Maleic Anhydride
Manganese
Methyl Chloroform(1,1,1, Trichloroethane)
Methylene Chloride
Nickel
Nitrobenzene
Nitrosomorpholine[a]
Perchloroethylene
Phenol
Phosgene[a]
Polychlorinated Biphenyls[a]
Propylene Oxide
Toluene[a]
Trichloroethylene[a]
Vinylidene Chloride
o-, m-, p-Xylene[a]

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[a] Included in compound-specific literature search.

bibliography recently compiled by Radian entitled "Air Toxics Information Clearinghouse: Bibliography of EPA Reports" can be used to supplement the references reviewed in this study.[1]

In Section 2, a summary of the report is presented. Section 3 describes the approach followed in generating the HAP data base and summarizes the computerized and manual literature search efforts. Section 4 presents a short summary of data and literature on major source categories identified in this study. Section 5 discusses the HAP control technology information in the data base. This section forms the body of the report. The first part of the discussion is based on the available data for HAP's emitted as vapors. The second part discusses the available data for HAP's emitted as particulates. Section 6 is the bibliography. A listing of the references identified during this study along with abstracts of those references are included in Section 6.1. The references are listed by topical content in Section 6.2.

SECTION 2

SUMMARY

This report describes a review of literature on sources of HAP's and control techniques employed in reducing and destroying HAP's. The report primarily focuses on HAP control technology. The information was abstracted from an extensive computerized and manual literature search and data base development study.

By definition, HAP's potentially can include thousands of compounds. For this reason, the references reviewed in this study do not encompass all the references in current HAP literature, rather they represent a small subset of the total HAP population. A large proportion of these HAP's are low-to-medium weight organic compounds with simple molecular structures. High-molecular weight compounds with complex structures are not included. In addition to organic compounds, the HAP's in this study include several metals. Inorganic HAP's (with the exception of metals) are not included in this study.

Major source categories of HAP emissions include the Synthetic Organic Chemical Manufacturing Industry (SOCMI), combustion, mobile sources, metal processing, and solvent use. Much of the emission source information reviewed for this study lies in the SOCMI area; combustion, mobile sources, metal processing, and solvent use source categories are not covered as extensively. For the combustion and metal processing categories, information was extracted from Radian in-house data bases.

From the literature review, it appears that point sources such as reactor vents and furnace stacks in manufacturing operations are well characterized with respect to emissions. But there are little data on process fugitive sources except in the coating and metal processing industries. Similarly, not much information is available on area sources with the exception of storage tanks, pump seals, and valves.

In the HAP control technology data base developed in this study, the majority of the data are for SOCMI. However, information on combustion, solvent use, and metal processing are also available. A large proportion of the control technology information pertains to point sources within the source categories and, therefore, add-on control technique applications are extensively covered.

Volatile organic compound (VOC) add-on control techniques identified in the literature are absorption, adsorption, combustion and condensation. Combustion techniques include catalytic and thermal incineration, flaring, and disposal of waste streams in boilers and process heaters. Based on the literature review, thermal incineration is applicable to a wide variety of compounds and is not very sensitive to HAP characteristics or waste stream conditions. The other control techniques, however, are dependent on HAP characteristics and process parameters.

The add-on control devices used for control of particulate HAP emissions are electrostatic precipitators (ESP's), baghouses, cyclones, and wet scrubbers. ESP's and baghouses have been widely used to control metal emissions; very high removal efficiencies are obtained with these devices. Wet scrubbers have been used for controlling both metal and organic particulate emissions.

Except for the solvent use source category, little data are available in the references for process fugitive and area sources. With the exception of SOCMI, work practices, process modifications, and material substitutions are not well documented.

SECTION 3

LITERATURE SEARCH

This section briefly describes the literature search methodology used by Radian to generate the HAP data base and the classification of the references in the data base.

Initially, a general literature search for HAP's was conducted. By definition, HAP's can potentially encompass hundreds of specific compounds. For this reason, the general HAP literature search produced a very large number of references relating to HAP's and control technology. Therefore, 14 compounds from the EPA's list of 37 potentially toxic substances for which Radian did not have in-house information were selected for a compound-specific literature search. These compounds are listed in Table 1-2. The EPA's list was chosen because it is a well-known list containing pollutants that are being studied by several organizations. Information on the remaining 23 compounds was available in Radian in-house project files from earlier studies. The literature search was supplemented by in-house data and on-going programs. The data base generated from the computerized and manual search efforts contains references that cover several other HAP's in addition to the compounds in Table 1-2.

For the computerized literature search, Radian screened the Compendex, Chemical Abstracts, and NTIS (National Technical Information Services) data bases. Description of the search and the key words used in each case are summarized in Table 3-1.

The list of references in the data base is presented in the Bibliography, Section 6. This list is used as the master reference list in the report. The numbers assigned to the references in the Bibliography are used throughout the report when a particular reference is cited.

TABLE 3-1. SUMMARY OF COMPUTERIZED LITERATURE SEARCH

	COMPENDEX	CA (Chemical Abstracts)	COMPENDEX	NTIS
Description of the Search	General literature search for HAP's	Compound-specific search	Compound-specific search	Compound-specific search (Air Pollution and Control and Pesticides Pollution and Control Sections of the data base were included. Biological and medical sciences and Water Pollution and Control Sections were excluded. The terms monitor, measurement, analysis, exposure, and occupational were also excluded.)
Key Words Used	noncriteria, toxic, hazard, chemical, gas, fume, emission, air pollution control, effluent, manufacture, source, plant, flare, condensation, carbon adsorption, thermal oxidation, incineration, hydrocarbon (Several combinations were used.)	acrolein, chlorobenzene, cresols, phosgene, coke oven emissions, PCB, benzyl chloride, chloroprene	acrolein, chlorobenzene cresols, phosgene, toluene, coke oven emissions, manufacture, plant, effluent	acrolein, benzyl chloride, chlorobenzene, cresol, dimethyl nitrosamine, hexachlorocyclopentadiene, toluene, xylene, PCB, trichloroethylene, coke oven emissions, phosgene, chloroprene, nitrosomorpholine

Most of the references in the data base are Government publications, journal articles, and papers presented at symposiums or conferences. All of the references included in the Bibliography have been obtained and reviewed to identify information pertaining to HAP emission sources and HAP control technology. During the review process, the references were organized and classified into six broad classifications (see Table 3-2).

A listing of the references within each of the six classification groups is included in Section 6.2, HAP Data Base Classification. The first group consists of references that provide data on the physical and chemical properties of HAP's. The second group of references contain data on manufacturers, production rate, and plant locations. References in the third group are those containing information on manufacturing processes and/or reactions associated with HAP emissions.

The fourth group includes references that contain HAP emission source information and data on emission factors and emission rates. In the fifth group of references under Emission Controls, information on actual plant control practices and/or applicable control techniques for several HAP's is available. These references contain data pertaining to HAP controls for organic compounds. The last group contains general references such as published literature searches.

TABLE 3-2. HAP DATA BASE CLASSIFICATION

Physical/Chemical Properties	7, 8, 9, 10, 11, 31, 32, 33, 34, 39, 40, 41, 42, 43, 45, 52, 53, 54, 55, 74, 75, 77, 78, 81, 118, 139, 142, 146
Manufacturing Information[a]	2, 3, 7, 8, 9, 10, 11, 13, 14, 19, 26, 28, 29, 31, 32, 33, 36, 44, 45, 52, 53, 54, 55, 56, 78, 81, 84, 89, 97, 98, 114, 125, 130, 139 146
Reaction/Process/Industry Descriptions[b]	2, 3, 7, 8, 9, 10, 11, 13, 14, 17, 18, 19, 20, 26, 27, 29, 31, 32, 33, 45, 52, 53, 54, 55, 56, 61, 74, 75, 77, 78, 81, 84, 97, 98, 102, 124, 127, 136, 137, 140, 142, 145, 146, 153, 154
Emission Sources/Rates/Factors[c]	2, 3, 4, 7, 8, 9, 10, 11, 13, 14, 17, 18, 19, 20, 22, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 49, 56, 61, 72, 73, 74, 75, 76, 77, 80, 81, 82, 83, 84, 85, 86, 87, 88, 90, 92, 95, 96, 101, 108, 110, 111, 113, 114, 115, 117, 120, 122, 124, 127, 128, 129, 132, 133, 134, 135, 136, 139, 140, 141, 143, 144, 146, 153, 154, 155, 156
Emission Controls[d]	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32, 38, 49, 50, 51, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 73, 74, 75, 81, 82, 83, 84, 90, 92, 97, 100, 101, 103, 104, 105, 106, 108, 109, 110, 112, 113, 115, 117, 119, 121, 125, 126, 131, 132, 135, 136, 137, 138, 140, 141, 143, 144, 145, 147, 148, 149, 150, 151, 152, 153, 154
General[e]	1, 46, 47, 48, 93, 99, 107, 116

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[a] This group includes references containing manufacturing data concerning producers, production rate, and plant location. Also included are the references that report HAP monitoring data at different locations.

[b] This group includes references that contain information on reactions and/or processes associated with HAP emissions. References that contain descriptions of industries emitting HAP's are also included in this group.

[c] This group contains references pertaining to emissions from production and/or consumption, storage and handling, as well as fugitive and secondary emissions. References with information on actual and/or estimated emission rates and factors are included in this group.

[d] In this group, the references relating to actual plant control practices and/or applicable control techniques for HAP's are included. This group also contains the references that have general information on control technology.

[e] This group includes general references such as published literature searches, Chemical Activities Status Report, etc.

SECTION 4

SOURCE CHARACTERIZATION

This section briefly discusses the major source categories that emit HAP's, based on a review of the references grouped under Emission Sources/Rates/Factors in Table 3-2. The discussion includes a brief description of emission sources, source types, and characteristics of HAP's emitted from each source category. The key references pertaining to each source category are indicated in the discussion. A recently completed Radian study entitled "Air Toxics Clearinghouse: Bibliography of EPA Reports" can provide additional references on the source categories.[1]

For the purposes of this review, a source category is defined as a general class of industries or activities. The source categories identified as emitting HAP's can be divided into five groups: (1) SOCMI, (2) combustion, (3) solvent use, (4) metals processing, (5) mobile sources, and (6) others.[35] The last group includes sources that do not fit in any of the other categories.

The SOCMI, solvent use, and mobile source categories primarily emit volatile organic HAP's. Metals and organic compounds are emitted from the combustion and mobile sources. Metals are also emitted from the metal processing sources.

HAP emissions from the SOCMI source category include emissions from production, feedstock use, indirect production (a by-product or contaminant), storage and handling, and waste disposal. The combustion source category produces emissions from boilers and furnaces used in power and heat generation in industrial, commercial/institutional, and residential sectors. The metal emissions from this source category are a result of the presence of metal impurities in coal or other fuels. Emissions from the solvent use source category are caused by use of organic chemicals as solvents in processes such as surface coating or graphic printing. The metal processing source category produces emissions from mining, refining, and production of alloys and other metal products. The HAP emissions occur during the recovery of the metal and during its use in manufacturing end products. The emissions from the mobile sources category are due to incomplete combustion or presence of impurities in the fuel used in gasoline or diesel-powered vehicles.

Source type refers to whether a pollutant is emitted from a point (process) source, process fugitive source or an area/fugitive source. Point sources are generally large and individually defined. Reactors, distillation column condenser vents, furnaces, and boilers are typical point sources which discharge emissions to the atmosphere through a vent-pipe or stack. Like point sources, process fugitive sources are individually defined. In order to control emissions from process fugitive sources, the emissions have to be captured by hooding or enclosure and transferred to a control device. Solvent use operations like degreasing and dry cleaning are process fugitive sources. Area sources are large and undefined. The emissions from these sources are difficult to capture and transfer to a control device. Examples of area sources include pump seals, valves, and waste treatment lagoons.

In the following sections, the HAP characteristics and source types for each source category are discussed in more detail.

4.1 SOCMI

The SOCMI source category is a significant source of potential HAP's and most of the existing HAP lists contain a large proportion of organic chemicals. The key references reviewed for information on SOCMI include

References 1, 2, 3, 4, 7, 8, 9, 10, 11, 29, 30, 31, 32, 35, 81, 97, 124, 131, and 135.

Major emission sources in this category are reactor vents, distillation column condenser vents, storage tanks, pressure relief valves, pump seals, waste treatment lagoons, accumulators, hot wells, and oil-water separators.[2,3] Reactor and condenser vents are point sources whereas waste treatment lagoons, valves, and seals are considered fugitive emissions sources. Process fugitive sources include oil-water separators and accumulators.

Table 4-1 lists pollutants primarily emitted by the SOCMI source category.[35] The emissions from this category are mainly associated with manufacturing processes. Also included in the table is an estimated percentage of national emissions of each SOCMI compound that is concentrated in SOCMI category as presented in Reference 35. In general, the emissions from this category are volatile compounds that are liquids or gases at ambient conditions; only very small percentage of the emissions are particulates. Most information in this category pertains to emissions from point sources. Emissions from process fugitive and area sources are not well characterized.

4.2 COMBUSTION

This source category includes utility, industrial, and institutional boilers; commercial and residential combustion units; process heaters; and furnaces. The key reference reviewed in this section is Reference 73. References 35, 72, 80, and 115 were also reviewed.

Most combustion units burn coal, oil, natural gas, or wood to generate heat or power. Other emission sources within this source category include cooling towers, coal storage piles, and ash handling systems. In general, combustion units are considered point sources since their emissions are discharged to the atmosphere through a stack. On the other hand, coal storage piles are area sources and ash handling operations are considered to

TABLE 4-1. POLLUTANTS EMITTED PRIMARILY BY THE SYNTHETIC ORGANIC CHEMICAL MANUFACTURING INDUSTRY (SOCMI)[35,a]

Pollutant	Estimated Percentage of National Emissions Concentrated in SOCMI Category
Acetonitrile	100
Acrylonitrile	
Allyl chloride	
Barium carbonate	
Carbonyl sulfide	
Chloroacetic acid	
Chloroethane	
Chloroprene	
Cumen	
1,2-Dibromoethane	
1-2-Dichloroethylene	
Dioctylphthalate	
Epichlorohydrin	
Ethyl acrylate	
Ethyl benzene	
Ethylene glycol	
Ethylene glycol monoethyl ether	
Ethylene oxide	
Hexachlorocyclopentadiene	
Hexahydro-2H-azepin-2-one	
Isopropyl alcohol	
4,4-Isopropylidenediphenol	
Maleic anhydride	
Melamine	
Methyl chlorine	
Methyl methacrylate	
4,4-Methylenedianiline	
Naphthalene	
Phenol	
Phosgene	
Phthalic anhydride	
Propene	
Propylene oxide	
Styrene	
Terephthalic acid	
Toluene diisocyanate	
Vinyl acetate	
Vinylidene chloride	↓
Ammonia	99.9
1,3-Butadiene	99.9

TABLE 4-1. POLLUTANTS EMITTED PRIMARILY BY THE SYNTHETIC ORGANIC CHEMICAL MANUFACTURING INDUSTRY (SOCMI)[35,a]

Pollutant	Estimated Percentage of National Emissions Concentrated in SOCMI Category
Benzyl chloride	99.0
Ethylene	98.6
Methanol	98.6
Acrylamide	97.4
Dimethyl nitrosamine	93.4
Ethylene dichloride	90.0

[a] In Reference 35, the study was based on 87 HAP. Therefore, the list of compounds in the table may not be considered complete.

be process fugitive sources. Emissions from coal storage piles are significant only in the utility sector.

HAP's from this source category are emitted as vapors or solid particles. The particulate emissions contain metals and organic species; gaseous emissions generally consist of volatile organic and inorganic compounds. Table 4-2 presents a list of compounds known to be emitted by combustion sources.[35] Also indicated in the table is an estimated percentage of national emissions of each pollutant concentrated in the combustion category as presented in Reference 35. Beryllium, chromium, and nickel account for large percentages, since they are present as impurities in the combustion fuel.

4.3 SOLVENT USE

Hazardous emissions from evaporation of organic solvents used in operations such as surface coating, dry cleaning, degreasing, and graphic arts are included in the solvent use category. The key references reviewed in this section are References 21, 27, 28, 29, 35, 61, 140, 143, and 144.

The emission sources within this category are considered process fugitive sources. Table 4-3 presents a list of compounds emitted from solvent use.[35] Most of these emissions consist of VOC's, such as aromatics, substituted aromatics, cyclic compounds, ketones, and chlorinated compounds. The table also contains estimates of the percentage of national emissions of each pollutant in the solvent use category as presented in Reference 35.

4.4 METAL PROCESSING

The metal processing source category includes emissions from mining, refining, and production of alloys and metal products. The key references reviewed in this section include References 35, 49, 74, 75, 77, 84, and 115.

TABLE 4-2. POLLUTANTS EMITTED FROM STATIONARY FUEL COMBUSTION SOURCE CATEGORY[35,73,a]

Pollutant	Estimated Percentage of National Emissions Concentrated in Stationary Fuel Combustion Category
Chlorine	98.2
Chromium	89.6
Beryllium	84.4
Nickel	84.2
Acetic acid	64.2
POM[b]	51.8
Acetaldehyde	42.0
Copper	24.2
Cadmium	23.9
Formaldehyde	17.5
Manganese	15.8
Zinc	3.7
Acrylamide	2.6
Ethylene	1.1
Ammonia	0.1
Arsenic	-[c]
Dioxin	"
Mercury	"
Vanadium	"

[a] In Reference 35, the study was based on 87 HAP's. Therefore, the list of compounds in the table may not be considered complete.

[b] POM is polycylic organic matter composed of compounds with two or more fused rings. Benzo(a)pyrene is a major constituent in POM emissions.

[c] Not included in Reference 35.

TABLE 4-3. POLLUTANTS EMITTED FROM SOLVENT USE[27,35,117,a]

Pollutant	Estimated Percentage of National Emissions Concentrated in Solvent Use Category
Cyclohexane	100.0
Methyl ethyl ketone	100.0
Chlorobenzene	99.2
Nitrobenzene	96.0
Perchloroethylene	93.6
Trichloroethylene	91.4
Methyl chloroform	78.6
p-Cresol	69.3
m-Cresol	68.3
o-Cresol	60.8
Acrolein	58.2
Methylene chloride	56.1
m-Xylene	54.0
o-Xylene	52.3
p-Xylene	48.5
Chloroform	47.5
Acetaldehyde	36.0
Ethylene dichloride	5.0
Methanol	1.4
Toluene	0.1
Acetone	-[b]
Carbon tetrachloride	"
Ethanol	"
Isopropanol	"
Methyl chloride	"
Methyl isobutyl ketone	"
Naphthalene	"
Phenol	"
Trichlorotrifluoroethane	"

[a] In Reference 35, the study was based on 87 HAP's. Therefore, the list of compounds in the table may not be considered complete.

[b] Not included in Reference 35.

Primary and secondary metal smelting operations, steel manufacturing, and ferroalloy reduction are some of the processes included in this category. The emission sources within this category are process, process fugitive, and area/fugitive type and are listed in Table 4-4 by source type for a number of industries. The major process emission sources are furnaces. Process fugitive emissions generally occur during furnace operations, charge preparation, casting, and refining operations. Area/fugitive emissions sources include leakage during furnace operations and other operations such as raw material handling and storage.

Table 4-5 lists some of the pollutants emitted from this category and their respective estimated percentages of national emissions as presented in Reference 35. Gaseous emissions include cyanides, acid mists, arsenic, and hydrogen sulfide. Evaporation of compounds such as cresols also result in gaseous emissions when they are used as flotation agents.

4.5 MOBILE SOURCES

In general, mobile sources include gasoline- and diesel-powered vehicles and aircraft. The references reviewed for this section are References 35, 86, 87, 88, and 140.

Mobile sources are considered area sources since they are broadly dispersed and small, mobile point sources. The emissions from this source category are mainly organic vapors resulting from incomplete combustion or thermal cracking of fuel. Table 4-6 presents several HAP's emitted from this source category and their respective estimated percentages of national emissions as presented in Reference 35. Most emissions from this category consist of aromatics including benzene, toluene, and xylene. Particulate emissions include POM and metals such as beryllium, nickel, and manganese.

TABLE 4-4. SOME METAL PROCESSING EMISSION SOURCES

Source Process Type	Point	Process-Fugitive	Fugitive/Area
Primary Copper Smelting	Roaster Smelter Converter	Slag tapping Matte tapping Calcine transfer Sinter handling	Ore concentrate unloading and handling Flue dust handling Slag dumping Leakage
Primary Zinc Smelting	Roaster Sinter machine Electrothermal furnace	Sinter preparation and recovery Furnace charging Sinter sizing and crushing	Ore concentrate unloading, handling and storage
Secondary Zinc Smelting	Sweat furnaces Pot furnaces Distillation retort	Charge preparation	Raw material handling and transfer Leakage
Iron and Steel Production	Sinter plant Blast furnace Steel furnace Coke oven	Charge preparation Furnace operations Coal charging	Raw material handling and transfer Leakage
Primary Cadmium Production	Retort furnace Smelter	Charge preparation Furnace operations	Raw material handling and transfer
Primary Lead Smelting	Sinter machine Blast furnace Dross furnace	Slag tapping Handling, treating, and charging of sinter into the sinter machine Casting Furnace charging and blowing	Handling and transfer of lead or concentrate Zinc fuming furnace Leakage
Secondary Lead Smelting	Blast furnace Smelting furnace Pot furnaces	Charge preparation Furnace charging Slag tapping Lead tapping Casting	Raw material storage Charge preparation area Product scrap materials handling Paved/unpaved roads

[a] References 49, 74, 75, 84.

TABLE 4-5. POLLUTANTS EMITTED FROM METAL PROCESSING[35,77,a]

Pollutant	Estimated Percentage of National Emissions Concentrated In Metal Processing Category
Zinc	96.3
Manganese	76.2
Copper	75.8
Cadmium	66.0
p-Cresol	10.4
m-Cresol	10.2
o-Cresol	9.1
Nickel	7.3
Beryllium	3.8
Zinc Oxide	1.7
Chromium	0.2
Arsenic	-[b]

[a] In Reference 35, the study was based on 87 HAP's. Therefore, the list of compounds in the table may not be considered complete.

[b] Not included in Reference 35.

TABLE 4-6. POLLUTANTS EMITTED FROM MOBILE SOURCES[35,a]

Pollutant	Estimated Percentage of National Emissions Concentrated In Mobile Source Category
Benzene	70.2
Toluene	61.6
p-Xylene	47.7
o-Xylene	45.9
m-Xylene	45.2
POM	42.6
Formaldehyde	32.6
Nickel	8.0
Ethylene dichloride	2
Beryllium	1.4
Acetaldehyde	Trace
Ammonia	"
Dioxin	"
Ethylene	"
Ethylene dibromide	"
Isobutyraldehyde	"
Manganese	"
Methyl ethyl ketone	"
Phenol	"
Propene	"

[a] In Reference 35, the study was based on 87 HAP's. Therefore, the list of compounds in the table may not be considered complete.

4.6 OTHER SOURCES

Other HAP sources do not readily fit in the first five source categories. Some of these sources are petroleum refining, distribution, and marketing; plastics, rubber, and resins production; waste incineration; paint, varnish, and printing inks manufacture; pesticide applications; coke production; and pharmaceuticals production. For a discussion of these sources, the reader is referred to References 14, 30, 37, 46, 82, 93, 96, 101, 111, 122, and 133. Additional references can also be found in "Air Toxics Clearinghouse: Bibliography of EPA Reports".[1]

SECTION 5

CONTROL TECHNOLOGY

This section presents a review and summary of the information contained in the references grouped under Emission Controls in Table 3-2.

The control techniques applicable for reducing or destroying emissions of a specific pollutant are generally dependent upon the characteristics of both the source and the pollutant. For example, point sources can readily be controlled by add-on control devices. Pollutant characteristics such as molecular weight, vapor pressure, molecular structure, and form (vapor or solid) are important factors in determining the type of control to be employed. Physical and chemical property data for several HAP's are summarized in Appendix A.

The majority of the references on control technology contain information for the SOCMI source category. In addition, data on controlling emissions from combustion, metal processing, and solvent use also are available.

Control information for the SOCMI, combustion, and metal processing categories pertains primarily to point sources. Much of the literature on the SOCMI category is associated with controls applied to manufacturing processes. Hence the major point sources are reactors and distillation column condenser vents. Within the combustion source category, the stacks from the boilers and furnaces constitute the point sources. In metal processing, the control information is based on emissions from furnaces, smelters, and sinter machines. For the solvent use category, most of the information is on process fugitive emissions control. These sources are concentrated in surface coating, dry cleaning, degreasing, and printing industries.

Many major point sources within several source categories have been studied as part of the EPA's Control Technique Guidelines (CTG), New Source Performance Standards (NSPS), and NESHAP development efforts. However, there is little information available on controls for area/fugitive emission sources with the exception of pump seals, valves, storage tanks, and surface coating operations.

Table 5-1 presents a summary of the add-on control devices employed in HAP emissions control, based on the literature review. Application of a particular control technique for a particular HAP, as shown in the table, indicates that the technique is used for controlling emissions from: (1) manufacture of the HAP, (2) processes where the HAP is used as a raw material or solvent, or (3) combustion sources where the fuel used contains the HAP as an impurity.

For SOCMI, control efficiency data are available for VOC removal in several references. However, there is very little information available on compound-specific removal efficiencies. In contrast, data from combustion, metal processing, and solvent use source categories do contain compound-specific information. Detailed control technology information for most of the HAP's in the table is summarized in Appendix B.

The HAP's in Table 5-1 are contained in several HAP lists and represent a subset of the total HAP population. The table contains a preponderance of VOC's characterized by low- to medium- molecular weight and simple molecular structure. High-molecular weight compounds with complex molecular structures are not included, although several HAP's fall in this group.

The majority of the organic HAP's in the table are liquids or gases at ambient conditions. Many of them are aromatics, olefins, aldehydes, ketones, esters, ethers, alcohols, and cyclic compounds. Some of these

TABLE 5-1. ADD-ON CONTROL TECHNIQUES USED FOR REDUCING EMISSIONS OF HAZARDOUS/TOXIC AIR POLLUTANTS

COMBUSTION			
Catalytic Incineration	Thermal Incineration	Boilers/Process Heaters	Flares
Acrylic acid	Acetic anhydride	Acetic anhydride	Acetaldehyde
Acrylonitrile	Acrolein	Acetone/Phenol	Acetic acid
Benzene	Acrylonitrile	Adipic acid	Acrolein
Butadiene[a,b]	Aniline	Butadiene[a]	Acrylic acid
Caprolactam	Benzene	Caprolactam	Acrylonitrile
Cumene	Benzyl chloride[c]	Cumene	Allyl alcohol
Ethylene dichloride	Butadiene[a]	Cyclohexane	Allyl chloride
Ethylene oxide	Dimethyl terephthalate	Cyclohexanol/Cychlohexanone	Butadiene[a]
Maleic anhydride	Epichlorohydrin	Dimethyl terephthalate	Chloromethanes[d]
Phthalic anhydride	Ethylene dichloride	Ethylbenzene/Styrene	Chloroprene
Phenol	Ethylene glycol	Ethylene oxide	Cumene
Vinyl acetate	Formaldehyde	Formaldehyde	Cyclohexane
	Maleic anhydride	Linear alkylbenzenes	Cyclohexanol/Cyclohexanone
	Methyl chloroform	Methanol	Ethylbenzene/Styrene
	Perchloroethylene/Trichloroethylene	Propylene oxide	Ethylene
	Phthalic anhydride		Ethylene oxide
	Polychlorinated biphenyls		Formaldehyde
	Terephthalic acid		Linear alkylbenzenes
	Toluene		Methanol
	Toluene diisocyanate		Methyl ethyl ketone
	Vinyl acetate		Methyl methacrylate
	Vinylidene chloride		Propylene oxide
			Vinyl acetate

TABLE 5-1. ADD-ON CONTROL TECHNIQUES USED FOR REDUCING EMISSIONS OF HAZARDOUS/TOXIC AIR POLLUTANTS (CONTINUED)

Absorption	Adsorption	Condensation	Fabric Filters	Wet Scrubbing	Electrostatic Precipitators (ESP)
Acetaldehyde[c]	Acetone/Phenol	Acetaldehyde	Adipic acid	Adipic acid	Cadmium
Acetic acid	Aceylonitrile	Acetic acid	Cadmium	Cadmium	Chromium
Acetone/Phenol	Adipic acid	Acetone/Phenol	Caprolactam	Chlorobenzene	Copper
Acrylonitrile	Aniline	Acrylic acid	Chromium	Chromium	Manganese
Acrylic acid	Benzene	Acrylonitrile	Copper	Dimethyl terephthalate	Nickel
Allyl alcohol	Benzyl chloride	Allyl alcohol	Dimethyl terephthalate	Maleic anhydride	Zinc
Allyl chloride	Carbon terephthalate/ Perchloroethylene	Allyl chloride	Manganese	Nickel	
Aniline	Chlorobenzene	Aniline	Nickel	Toluene diisocyanate	Cyclones
Benzene	Chloroform	Benzene	Terephthalic acid	Phthalic anhydride	
Benzyl chloride[c]	Cyclohexane	Benzyl chloride[c]	Zinc	Zinc	Cadmium
Butadiene[a]	Dimethyl terephthalate	Butadiene			Copper
Caprolactam	Ethylene dichloride	Caprolactam			Nickel
Carbon tetrachloride/ Perchloroethylene	Maleic anhydride	Carbon tetrachloride			Zinc
Chlorobenzene	Methyl chloride	Chloroprene/Neoprene			
Chloromethanes[d]	Methyl ethyl ketone	Chlorobenzene			
Chloroprene	Methyl methacrylate	Chloromethanes[d]			
Chloroprene/Neoprene	Methylene chloride	Chloroprene			
Cyclohexanol/Cyclohexanone	Phosgene	Dimethyl terephthalate			
Dimethyl terephthalate	Styrene	Ethylbenzene/Styrene			
Epichlorohydrin	Terephthalic acid	Ethylene dichloride			
Ethylbenzene/Styrene	Toluene	Ethylene oxide			
Ethylene dichloride	Toluene diisocyanate	Ethylene glycol			
Ethylene oxide	Vinyl chloride	Fluorocarbons			
Fluorocarbons	Xylene	Formaldehyde			
Maleic anhydride		Linear alkylbenzenes			
Methanol		Methyl chloroform			
Methyl chloroform		Methyl chloride			
Methyl ethyl[f] ketone		Methyl methacrylate			
Nitrobenzene		Nitrobenzene			
Perchloroethylene/ Trichloroethylene		Perchloroethylene/ Trichloroethylene			
Phosgene		Toluene			
Phthalic anhydride		Toluene diisocyanate			
Propylene oxide		Vinylidene chloride			
Vinylidene chloride		Xylene			
Xylene					

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[a] In this report, butadiene refers to 1,3 butadiene.

[b] Not currently used.

[c] Possible control technique.

[d] Chloromethanes include methyl chloride, methylene chloride, chloroform, and carbon tetrachloride. Individual compound is listed whenever specific information is available.

compounds contain nitrogen, and several are chlorinated hydrocarbons; only a small percentage of the HAP's are particulates. With the exception of metals, no inorganic compounds are included in the table.

In the following sections, control technology information compiled from the literature review is summarized. Section 5.1 presents the information for VOC emissions, and Section 5.2 presents the information for particulate emissions. In each section, factors affecting control device selection and performance are also discussed.

The reader is cautioned to view the control efficiency data reported in this study with a critical eye. The data are presented as contained in the literature, and no judgment regarding the accuracy is made. For more details on specific data, the reader is encouraged to consult the references.

5.1 VOLATILE ORGANIC COMPOUND EMISSIONS CONTROL

This section summarizes information available in the data base pertaining to control of HAP's that are emitted as gases and vapors. Most of this information applies to the SOCMI, but some data on controlling VOC emissions from the solvent use source category are also available.

Emissions from SOCMI are primarily VOC's. Much of the literature in this area pertains to actual controls employed to reduce/recover VOC emissions during manufacturing processes. Therefore, the information is focused on point source controls for most of the SOCMI compounds. Although control efficiency data are available for overall VOC removal in most of the references, very little information is available for compound-specific removal efficiencies.

The literature on control of emissions from the solvent use category concentrates on process fugitive sources. Compound-specific control information is available for some compounds, but very little information was found for compound-specific control efficiencies.

The following is a discussion of the major add-on VOC control techniques identified in the literature search: combustion, adsorption, absorption, and condensation. In each part, the findings from the literature review are summarized, preceded by a brief description of the control technique. The description is intended only to familiarize the reader with the control technique; hence, it may not be complete. For more information, the reader is referred to the references cited within each section.

5.1.1 Combustion Control Techniques

Combustion control techniques are the most universally applicable control methods for volatile organic HAP's. Organic gaseous or particulate air emissions are destroyed by oxidation to carbon dioxide and water vapor. A properly designed and operated combustion device is capable of destroying any organic compound.[28] Emission control by combustion results in the destruction of the pollutants in the waste stream. Although the process materials cannot be recovered, this method offers the potential for recovery of heat released during combustion.[25]

When used as a control technique, the combustion process is usually carried out in thermal or catalytic incinerators with the use of supplemental fuel.[22] Under proper conditions, the firebox of a process heater or boiler can also serve as an emission control device.[125] Another combustion control technique practiced in industry is flaring.[22]

Based on the literature search, the combustion techniques used for controlling volatile organic HAP's include incineration (thermal and catalytic), use of waste gas as supplementary fuel, and flaring.

5.1.1.1 Thermal Incineration--

Introduction--The combustion process in a thermal incinerator is mainly influenced by three factors: chamber temperature, residence time, and turbulence.[5,22,23,125] The chamber temperature in an efficient thermal oxidizer should be high enough for complete oxidation of the combustibles. The residence time at the chamber temperature should be long enough to ensure completion of the combustion process. At a constant residence time, the destruction efficiency in a thermal incinerator increases with temperature.[28] When operating at a constant temperature, the destruction efficiency in a thermal incinerator increases with residence time.[28] Turbulence and adequate mixing between the combustion products from the burner, combustion air, and the waste gas stream is essential for efficient combustion control. At temperatures over 1,400°F, the oxidation rate is much faster than the rate at which mixing takes place. Therefore, VOC destruction efficiency becomes more dependent on fluid mechanics at high temperatures.

In addition to temperature, residence time, and mixing effects, the VOC destruction efficiency is affected by the inlet pollutant type.[125] Although destruction of most VOC's occur rapidly at temperatures above 1,400°F, higher chamber temperatures are required when burning compounds such as halogenated hydrocarbons.[5]

Thermal incineration as an emission control technique is much less dependent on HAP characteristics and waste stream conditions than the other control techniques such as absorption, adsorption, condensation, and catalytic oxidation.[125] This technique is not as sensitive to the physical and chemical properties of HAP's, HAP concentration, waste stream flow rate, composition, and waste stream contaminants as the other control techniques. However, costs of thermal oxidation systems are affected by the composition of the waste stream. For example, waste gases containing sulfur or halogens require flue gas scrubbing after incineration to remove the noxious gases formed during oxidation. The heat content of the waste stream is a major factor in determining supplementary fuel requirements, hence its effect on the operating costs.

Summary--Based on the literature search, Table 5-2 summarizes the applications of thermal incineration as an emission control technique in industry. This information has been compiled from the 15 references indicated in the table. In addition, 12 other references in the data base were reviewed. These include References 24, 25, 27, 28, 29, 57, 61, 65, 67, 69, 132, and 137.

Review of the references has indicated that thermal incineration is the most universally applicable control technique. As shown in Table 5-2, compounds controlled by thermal incineration include saturated and unsaturated alkyl halides, aldehydes, esters, nitro-compounds, carboxylic acids, and aromatics. Very high control efficiencies (up to 100 percent) are obtained by using this method. Of the 42 reported control efficiencies in Table 5-2, 37 are in the 90-100 percent range.

The data are generally reported for VOC's as a group. Hence, no compound-specific thermal incineration data could be identified from the literature search. Since the overall removal efficiency is not necessarily equivalent to compound-specific removal efficiency, the data should be used with caution.

In addition to the data compiled in Table 5-2 for industrial thermal incinerators, test data from a laboratory scale incinerator are available.[125] Some of the results are shown in Table 5-3. Since the lab unit was designed for optimum mixing, the results represent the upper limit of incinerator efficiency. The results of complete backmixing would be more comparable to those obtained from large scale units. Table 5-4 illustrates the effect of mixing by comparing the performance of a commercial incinerator with that of a laboratory unit.

TABLE 5-2. SUMMARY OF THERMAL INCINERATOR DATA[a]

Compound	Temp. (°F)	Inlet conc. (ppmv)	Outlet conc. (ppmv)	Composition[B]	Flow rate scfm	Residence time (sec)	Heat recovery[C]	Control efficiency[D] (%)	References
Acetic anhydride		20.7[a]		Y	91		Y[b]		11
Acrylic acid[a,b]	1,425[c]	2,580[d] 11,600[e]	1,330		52,500[f]	1.0		82.6	5, 81, 125
	1,510[g]	2,600[d] 12,800[e]	150		52,500[f]	1.0		98.3	
	1,545[h]	2,410[d] 12,200[e]	25		52,500[f]	1.0		99.7	
	1,160[i]	11,900	243		20,600	2-3	Y[j]	96.1	
	1,475[k]	11,900	10		20,600	2-3	Y[j]	99.9	
Acrolein[a]									5, 11, 125
Acrylonitrile[a]	Confidential	Confidential	25		75,000 (average)			>99	5, 125
			47		75,000 (average)			>99	
Aniline[a]								>99.9[b]	8
Benzene[a]									5, 7, 8, 62, 125
Butadiene[a]	1,400	10,300	1,400		7,250	0.6	Y[b]	70.3[c]	5, 62, 125
	1,400	10,650	215		15,617	0.6		94.1	
	1,400	10,650	215		20,750	0.6		94.1	
	1,400	10,300	10		15,867	0.6		99.6	
	1,400	10,300	10		12,500	0.6		99.6	
	1,300	0.4[d]			23,500[f]	0.5	Y[b,e]	93[g]	

TABLE 5-2. SUMMARY OF THERMAL INCINERATOR DATA[a] (CONTINUED)

Compound	Temp. (°F)	Inlet conc. (ppmv)	Outlet conc. (ppmv)	Composition[B]	Flow rate scfm	Residence time (sec)	Heat recovery[C]	Control efficiency[D] (%)	References
Dimethyl terephthalate[a,b]							Y[c]	~100	8
Epichlorohydrin									11
Ethylene dichloride		29[a]		Y	500[b]				9
		56[a]		Y	700[b]				
Ethylene glycol[a]									10
Formaldehyde	2,000	0.87[a]		Y			Y[b]	100	10, 125
								100	
								98.8	
Maleic anhydride	<2,000	834	7	Y	33,200	0.6	Y[c]	98.96	5, 7, 62, 125
	<2,000	834	8	Y	24,200	0.6		98.96	
	1,400	950	13		33,000	0.6	Y	98.5	
	1,400	950	13		33,000	0.6		98.5	
	1,400	950	13		33,000	0.6		98.5	
	1,400					0.7			
	1,350					0.7		91[d]	
	1,500					0.7		96[d]	
	1,400	0.25[e]			220,000[b]	0.7		93[d]	
Methyl chloroform[a]								>98[b]	9
Nitrobenzene[a]									8

TABLE 5-2. SUMMARY OF THERMAL INCINERATOR DATA[a] (CONTINUED)

Compound	Temp. (°F)	Inlet conc. (ppmv)	Outlet conc. (ppmv)	Composition[B]	Flow rate scfm	Residence time (sec)	Heat recovery[C]	Control efficiency[D] (%)	References
Perchloroethylene/ Trichloroethylene	1,425			Y		0.4		>99	9
Phthalic anhydride	1,700[b]				6,000[c]			96[d,e]	97, 131 145
	1,200[g]						Y	90[d]	
	1,400						Y[h]	97[d] 99.5[f]	
	1,200[i]							95[d]	
	1,200[j]							99[d]	
	1,200, 1,600[j]							>99[d] 23[k]	
					293[c,l]			85[l]	
								80[l]	
Terephthalic acid[a]									8
Toluene[a]								91	144
Toluene diisocyanate[a]									8
Vinyl acetate		0.3		Y	600[b]				10
Vinylidene chloride								98	9

[A] Footnotes for each compound are numbered separately in alphabetical order on the next page.
[B] Y indicates that data on waste stream composition are available. These data are presented in Appendix B.
[C] Y indicates that heat is recovered from the thermal incinerator flue gases.
[D] Control efficiencies are reported as VOC destruction efficiencies. VOC concentrations are expressed as weight percent and do not include methane or ethane. Data where the efficiencies are reported in terms of other criteria are indicated in the footnotes.

TABLE 5-2. SUMMARY OF THERMAL INCINERATOR DATA[a] (CONTINUED)

Acetic anhydride

[a] 20.7 mole percent VOC.
[b] A waste heat boiler is used to produce steam.

Acrylic acid

[a] The first three sets of data were taken at Rohm and Haas's acrylic acid and ester production facility at Deer Park, TX. The last two sets of data were collected at Union Carbide's acrolein, acrylic acid, and ester manufacturing site at Taft, LA.
[b] The installed capital cost of the incinerator at Rohm and Haas's facility is $4.7 million. The estimated annual operating cost due to supplemental fuel is $0.9 million. The installed capital cost of the Union Carbide incinerator is $3 million. The annual operating cost in 1976 excluding capital depreciation is $287,000.
[c] Three tests were performed at these conditions.
[d] Concentration of the tank farm vent.
[e] Concentration of the oxidizer vent.
[f] 52,500 scfm = 12,500 scfm (tank farm vent) + 40,000 scfm (oxidizer vent).
[g] Four tests were performed at these conditions.
[h] One test was performed at these conditions.
[i] Six tests were performed at these conditions.
[j] The incinerator system is equipped with a heat recovery unit that produces process steam at 600 psig.
[k] Three tests were performed at these conditions.

Acrolein

[a] Refer to information given for acrylonitrile.

Acrylonitrile

[a] The data were collected at Monsanto Chemical Intermediates Company, Alvin, TX.

Aniline

[a] Thermal incineration is employed to control benzene emissions from the reactor purge vent. It is also used for treatment of catalyst and other wet and solid wastes.
[b] This is the overall efficiency reported for the combined process and secondary sources.

Benzene

[a] Benzene emissions due to impurities in the feedstock in aniline production and from maleic acid production where benzene is used as a raw material are controlled by thermal incineration. Refer to aniline and maleic anhydride in this table for more information.

Butadiene

[a] All the data were taken at Petro-tex Chemical Corporation's butadiene manufacturing facility in Houston, TX.
The installed capital cost of the incinerator system is reported as $2.5 million based on 1976 dollars.
[b] The incinerator design incorporates flue gas recirculation and a waste heat boiler. With variable waste gas flow, a constant 100,000 lbs/hr of 750 psi steam is generated.
[c] This reduction efficiency refers to the data taken prior to adjustments made to the incinerator. The specific adjustments involved changes in mixing induced by retrofit baffles.
[d] The inlet concentration is reported in terms of weight percent of hydrocarbons.
[e] Heat efficiency is reported as 82 percent.
[f] Flowrate is reported in lb/hr.
[g] The reduction efficiency with respect to hydrocarbon emissions is 93 percent.

TABLE 5-2. SUMMARY OF THERMAL INCINERATOR DATA[a] (CONTINUED)

Dimethyl terephthalate

[a] The wastewater for dimethyl terephthalate production containing methanol, formic acid, acetic acid, and formaldehyde are incinerated. Undesirable products formed during the esterification process such as dimethyl ether, methyl acetate, methyl p-toluate and benzoate and methyl p-formyl benzoate are also incinerated.

[b] The installed capital cost of the incinerator system is reported as 3.97 $/M lb of product. The annual operating cost is 0.88 $/M lb of product. These cost figures are based on 1973 dollars.

[c] A waste heat boiler is used to produce steam.

Ethylene dichloride

[a] Inlet concentration is expressed as VOC.

[b] VOC emission rate in lb/hr.

Ethylene glycol

[a] Gases from vent condensers in ethylene glycol production are routed to the thermal oxidizer.

Formaldehyde

[a] Inlet concentration is expressed as VOC.

[b] A waste heat boiler is used to produce steam.

Maleic anhydride

[a] The first two sets of data were taken at the maleic anhydride manufacturing facility of Koppers Company, Inc. in Bridgeville, PA. The next six data sets were collected at Denka's facility in Houston, TX. The data from Denka's facility show normal operating conditions and the change in efficiency when the temperature is varied. The last data point is from Petro-Tex Chemical Corp., Houston, TX.

[b] The installed capital cost of the Petro-Tex incinerator is reported as $1.75 million based on 1975 dollars.

[c] A waste heat boiler is used to produce steam.

[d] The efficiency figure refers to hydrocarbon reduction.

[e] Inlet concentration is expressed as hydrocarbon weight percent.

[f] Flowrate is reported in lb/hr.

Methyl chloroform

[a] The emissions are recycled to the ethylene dichloride process where the VOC's are either consumed or combined with other process emissions and eventually incinerated.

[b] Estimated efficiency.

Nitrobenzene

[a] Streams containing oxides of nitrogen and benzene are destroyed by incineration.

Phthalic anhydride

[a] The installed capital cost of two incinerator systems are reported as $280,000 and $250,000 based on 1968 and 1972 dollars, respectively. The annual operating costs are reported as $292,000 and $55,000 based on 1969 and 1972 dollars, respectively.

[b] An oil-fired thermal incinerator is used to incinerate the solution bled from the scrubber.

[c] Flowrate is in lb/hr.

[d] Efficiency is reported for total organics.

[e] Estimated efficiency.

[f] Efficiency is reported for carbon monoxide.

[g] Process vent gas is burned in an incinerator that was originally designed to burn waste water and hydrocarbons.

[h] The waste heat boilers produce steam at 750°F and gage pressure of 650 psi.

TABLE 5-2. SUMMARY OF THERMAL INCINERATOR DATA[a] (CONTINUED)

[i] The data are for a small thermal incinerator processing phthalic anhydride unit vent gas (naphthalene feedstock).
[j] This unit incinerates eject exhaust and reject hydrocarbons from product fractionation.
[k] The efficiency is reported as destruction of reactive hydrocarbons.
[l] The data are for units burning emissions from naphthalene feedstock based process.

Terephthalic acid

[a] Byproducts, residues from the reaction and distillation columns, the unrecoverable portions of the product, and inorganic portions of the catalyst are disposed of in a rotary kiln incinerator.

Toluene

[a] The information is based on rubber manufacturing where toluene is used as a solvent.

Toluene diisocyanate

[a] The light ends from toluene diamine vacuum distillation columns are condensed and burned in a liquid incinerator.

Vinyl acetate

[a] Inlet concentration is 0.3 weight percent ethylene.
[b] Flow rate is in lb/hr.

TABLE 5-3. RESULTS OF DESTRUCTION EFFICIENCY UNDER STATED CONDITIONS[125] (UNION CARBIDE TESTS)

		Residence Time/Compound				
			0.75 Sec			0.5/1.5 Sec
Flow Regime[b]	Temperature (°F)	Ethyl Acrylate	Ethanol	Ethylene	Vinyl Chloride	Ethylene
Two-stage Backmixing	1300	99.9	94.6	92.6	78.6	87.2/27.6
	1400	99.9	99.6	99.3	99.0	98.6/99.8
	1500	99.9	99.9	99.9	99.9	99.9/99.9
	1600	99.9	99.9	99.9	99.9	99.9/99.9
Complete Backmixing	1300	98.9	86.8	84.4	69.9	78.2/91.5
	1400	99.7	96.8	95.6	93.1	93.7/97.8
	1500	99.9	99.0	98.7	98.4	98.0/99.0
	1600	99.9	99.7	99.6	99.6	99.4/99.8
Plug Flow	1300	99.9	99.9	99.5	90.2	97.3/99.9
	1400	99.9	99.9	99.9	99.9	99.9/99.9
	1500	99.9	99.9	99.9	99.9	99.9/99.9
	1600	99.9	99.9	99.9	99.9	99.9/99.9

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[a] The results of the Union Carbide work are presented as a series of equations. These equations relate destruction efficiency to temperature, residence time, and flow regime for each of the 15 compounds. The efficiencies in this table were calculated from these equations.

[b] Three flow regimes are presented: two-stage backmixing, complete backmixing, and plug flow. Two-stage backmixing is considered a reasonable approximation of actual field units, with complete backmixing and plug flow representing the extremes.

TABLE 5-4. RESULT COMPARISONS OF LAB INCINERATOR VERSUS ROHM AND HAAS INCINERATOR[125, a]

	Rohm & Haas Incinerator		Union Carbide Lab Incinerator	
Compound	Inlet (lbs/hr)	Outlet (lbs/hr)	Inlet (lbs/hr)	Outlet (lbs/hr)
Propane	900	150	71.4	0.64
Propylene	1,800[b]	150[b]	142.9	5.6
Ethane	10	375	0.8	3.9
Ethylene	30	190	2.4	3.4
TOTAL	2,740	865	217.5	13.54
% VOC Destruction	68.4%		93.8%	

[a] Table shows the destruction efficiency of the four listed compounds for the Rohm & Haas (R&H) field and Union Carbide (UC) lab incinerators. The R&H results are measured; the UC results are calculated. Both sets of results are based on 1425°F combustion temperature and one second residence time. In addition, the UC results are based on complete backmixing and a four-step combustion sequence consisting of propane to propylene to ethane to ethylene to CO_2 and H_2O. These last two items are worst case assumptions.

[b] Not actual values. Actual values are confidential. Calculations with actual values give similar results.

References 8, 62, 97, and 125 provide actual thermal incinerator cost data for seven units as indicated in Table 5-2. General thermal incinerator cost data based on design considerations are available in several EPA Background Information Documents. References 5, 21, 22, 23, 28, and 132 also contain such information.

5.1.1.2 Catalytic Incineration--

Introduction--Catalytic incineration is a combustion control technique in which the oxidation reaction occurs at lower temperatures than thermal incineration with the help of a catalyst. The waste stream is contacted with a catalyst bed (or catalyst matrix structure) to allow oxidation reactions to occur rapidly in the temperature range 700 - 900°F. By contrast, a range of 1300 - 1500°F is required for practical oxidation rates in thermal incinerators.[141] Thus, significant energy savings are possible using catalytic incineration.[5,28] Combustion catalysts include platinum, palladium alloys, copper oxide, chromium and cobalt.[125]

The steps involved in the catalytic combustion process include: (1) mass transfer of combustibles and oxygen to the external catalyst surface (2) diffusion of combustibles and oxygen into the pores of the catalyst, (3) adsorption of combustibles and/or oxygen on the active catalytic sites, (4) reaction (oxidation) at the active site, (5) desorption of products from the catalyst sites, (6) diffusion of products through the pores of the external catalyst surface, and (7) mass transfer of products from the catalyst surface into the waste gas stream.[5,125,141]

Catalytic incineration is more sensitive to process conditions and pollutant characteristics than thermal incineration. The catalytic incinerator destruction efficiency is dependent on several parameters including the type and amount of catalyst used per unit volume of gas processed, incinerator temperature, residence time, and waste stream concentration and composition.[5,125] Greater efficiencies can be achieved by increasing the amount of catalyst used, although this may not be economical.[125]

Because of safety considerations, it is the general practice to keep the concentration of VOC's at less than 25-30 percent of the lower explosive level (LEL). Dilution of waste streams with high heat content might be necessary to prevent catalyst deactivation and melting of catalytic support. Other factors that influence the performance of a catalytic incinerator are accumulation of deposits such as carbon on active sites and poisoning of the catalyst by sulfur, chloride, lead, zinc, and antimony containing compounds.

Summary--Tables 5-5, 5-6, and 5-7 summarize the information on applications of catalytic incineration as an emission control technique. In Table 5-5, the majority of the data is for manufacturing emissions of SOCMI compounds. The data in Tables 5-6 and 5-7 pertain to solvent use operations such as coating and printing industries. In addition to the references reviewed in compiling the data in the tables, other references containing information related to catalytic incineration were reviewed. These include References 21, 22, 23, 24, 25, 28, 29, 57, 69, 132, and 138.

The literature review has indicated that catalytic incineration is not as widely used as thermal incineration. Catalytic incineration has been applied in controlling emissions of mainly nonchlorinated compounds such as olefins, aromatics, oxygen and nitrogen-containing compounds.

General catalytic incinerator cost data based on design are available in References 5, 21, 22, 23, 32, and 47.

5.1.1.3 Flaring--

Introduction--Flares are used to safely destroy waste gases by combusting them when: (1) the heating value cannot be recovered

TABLE 5-5. SUMMARY OF CATALYTIC INCINERATION DATA[a]

	Operating Temperature (°F)	Inlet Concen.	Composition[B]	Flowrate (lb/hr)	Residence Time (sec)	Heat Recovery[C]	Control Efficiency[D] (%)	Reference
Acrylic acid[a]								11
Acrylonitrile			Y				24[a]	11,
	750	4327[b]		76,115[c]		Y	42.5	151
Benzene								7
Butadiene[a]	115	0.5[b]		900,000 (total) 13,000 (Puff reactor)	0.3	Y[c]	92[d]	11, 62
							50[e]	
Caprolactam								5
Cumene								5
Ethylene dichloride	1.37[a]						99.7 (wrt CO, C_2H_4) <75% (wrt $C_2H_2Cl_2$) <60% (wrt vinyl chloride)	5, 9
Ethylene oxide								5, 10
Formaldehyde	1000	2000[a]		1,000[b]			97.9	5, 125 151
	800			3,000[b]			98.5	
	1000			1,740[b]			98.3	
							97.9	
	940			2,400			98.3	
	950			2,700			98.0	
Maleic anhydride								7
Phenol[a]	625[b]			23-27,000/hr[c]			92[b]	63
	725[b]			"			94[b]	
	825[b]			"			98[b]	
Phthalic anhydride[a]	800-1000						42-60[b]	5, 97, 141, 145
Vinyl acetate							97.5	10

[A] Footnotes for each compound are numbered separately in alphabetical order on the next page.

[B] Y indicates that data on waste stream composition are available. These data are presented in Appendix B.

[C] Y indicates that heat is recovered from the incinerator flue gases.

[D] Control efficiencies are generally reported as VOC destruction efficiencies. VOC concentrations are expressed as weight percent and do not include methane or ethane. Data where the efficiencies are reported in terms of other criteria are indicated in the footnotes.

TABLE 5-5. SUMMARY OF CATALYTIC INCINERATION DATA[a]

Acrylic acid

[a] Catalytic incineration is used for destroying acrylic acid emissions from product handling.

Acrylonitrile

[a] Propane destruction efficiency.
[b] Inlet concentration is in lb/hr VOC.
[c] Flowrate is expressed as scfm.

Butadiene

[a] The data are for Petro-Tex Chemical Corp., Houston, TX. The emissions from Houdry manufacturing process were controlled by catalytic incineration. However, the process was shut down in 1977.
[b] Concentration is expressed as percent hydrocarbon.
[c] Waste heat boilers are used for steam generation. Energy recovery efficiency from combustion gases is 80 percent.
[d] Efficiency expressed as hydrocarbon destruction.
[e] The reported efficiency is for the ARCO plant in Channelview, Texas. This plant was shut down in 1976.

Ethylene dichloride

[a] Concentration is expressed as VOC.

Formaldehyde

[a] Inlet concentration is expressed as ppm.
[b] Flow rate is expressed as scfm.

Phenol

[a] The data are from pilot studies using Econ-Acat catalyst at a phenol production plant. The amount of catalyst used was 225 lbs.
[b] The temperature and efficiency figures are read from a graph of catalyst outlet temperature versus conversion efficiency.
[c] Space velocity.

Phthalic anhydride

[a] The data are for phthalic manufacturing process using naphthalene feedstock.
[b] Combustion efficiency.

TABLE 5-6. CATALYTIC INCINERATOR PERFORMANCE DATA[a]

Process	Operating Temperature (°F)	Heat Recovery[b]	Flow Rates Inlet (scfm)	Flow Rates Outlet (scfm)	VOC Concentration Inlet (ppm)	VOC Concentration Outlet (ppm)	Control Efficiency[c] (%)	Energy Usage (Btu/hr)
Printing Press	810		8,000	8,800	728	39	94	
Drying oven	650	Y	18,892	18,892	1,800	160	91	
Drying oven	680	Y	15,335	15,335	2,700	160	94	
Drying oven	700	Y	2,371	2,371	4,200	300	93	
Drying oven	800	Y	1,939	1,939	5,000	320	94	
Drying oven	750	Y	3,800	3,800	2,293	122	94.7	
Drying oven	850	Y	3,800	3,800	3,121	90	97.1	
Drying oven	650	Y	3,900	3,900	3,045	200	91.6	
Litho oven	1035	Y	3,320	3,290	6,390	818	87	2,800,000
Litho oven	1145	Y	3,320	3,290	6,800	530	90	2,800,000
Litho oven	800	N	2,600	2,600	3,920	346	91	4,200
Coating line	730			6,293	530	15	97.1	
Coating line	735			5,585	227	15	93.4	
Coating line	720			3,987	478	20	95.8	
Paint line	520	N	12,600 5,480	23,400	244[d]	19[d]	92.2	
Post dry ovens		Y	4,300		2,800			
2 spreader ovens		Y	6,200		13,270			
Spreader/oven		Y	5,956	7,319	1,350	115	90.6	
Litho oven	980		1,530	1,410	14,265	511	97	
Litho oven	1050		1,410	1,270	9,390	673	94	
Litho oven	1030		1,410	1,370	21,000	180	99	
Printing press	1170	N	1,423	1,400	3,835	370	90.5	6,400,000
Lithographic press	850	N	2,190	2,300	602	99	86	960,000

[a] Reference 151.

[b] Y indicates that heat is recovered from the incinerator flue gases.
N indicates that heat is not recovered from the incinerator flue gases.

[c] Efficiency is reported in terms of VOC concentration.

[d] Concentrations are expressed as lb/hr VOC.

TABLE 5-7. PERFORMANCE DATA FOR CATALYTIC INCINERATORS[a]

Process	Major Solvents Identified[b]	Average Temperatures Catalyst Inlet/Outlet (%)	VOC Concentrations Inlet (ppmv)	VOC Concentrations Outlet (ppmv)	Flowrate (scfm)	Heat Recovery	Average Energy Usage (Btu/scf)	Catalyst Type	Destruction Efficiency (%)[d]
Can coating	toluene, xylenes, ethyl benzenes	685/745	4000-5810	181-275	7600	Y	7.2	ceramic honeycomb	95.4-96.4
Can coating	MIBK, xylenes, methyl and ethyl benzenes	600-770	2840-7760	173-321	6780	Y	6.1	ceramic honeycomb	93.4-95.9
Can coating	MIBK, xylenes, methyl and ethyl benzenes	600-770	2270-5755	46-341	6780	Y	6.1	ceramic honeycomb	96.3-98.6
Can coating	MIBK, cellosolve, xylenes, ethylbenzene	630/740	5480-7560	385-687	5330	N	6.9	ceramic honeycomb	88.7/94.0
Graphic Arts Printing	C_{12} to C_{18} hydrocarbons	920/820	1020	169	2000	N	21	ceramic honeycomb	81.2
Graphic Arts Printing	C_{12} to C_{18} hydrocarbons	701/713	1240	241	2660	Y	4.3	ceramic spherical pellets	80.1
Graphic Arts Printing	C_{12} to C_{18} hydrocarbons	667-774	1370-4030	90-165	4670	Y	2.1	ceramic spherical pellets	93.4-95.9
Magnet Wire	phenol, cresols	740/945	8720	1590	603	N	6.4	metal ribbons	80.6
Coil Coating	MEK, toluene	545/800	6220-12,860	272-305	11300	Y	3.9	ceramic honeycomb	96.5-97.5

[a] Reference 152.
[b] MIBK = methyl isobutyl ketone.
MEK = methyl ethyl ketone.
[c] Y indicates that heat is recovered from incinerator flue gases.
N indicates that heat is not recovered from incinerator flue gases.
[d] Efficiency is expressed in terms of VOC concentration.

economically because of intermittent and uncertain flow, or (2) when process upsets occur.[7,22,148,149] Flares are used extensively to burn purged and waste gases from refineries, petroleum production, chemical plants, coke ovens, and blast furnances.[149]

If the waste gas to be flared does not have sufficient heating value to sustain combustion, auxiliary fuel may be added. Most large flares are the natural draft type with optional steam injection to enhance fuel and air mixing. Water spray, high pressure gas or air may also be employed to improve mixing. Small flares may use fans to promote mixing before injection.

There are two major types of flare configurations: elevated and ground flares.[70,149] Elevated flares have larger capacities than ground flares. They typically consist of a flare stack and one or more elevated flare tips which stabilize the flame. A ground flare consists of an enclosure which confines the flame. The number of burner heads in a ground flare varies with the capacity of the ground flare. Since the flame is enclosed, it is not affected by wind or precipitation. Ground flares are typically used to dispose of small amounts of gas continuously while elevated flares are used to dispose of large amounts of gas released in emergencies.

Summary--The literature review has indicated that flares are commonly used as emission control devices. Table 5-8 summarizes the information found in the data base on flare applications in the SOCMI industry. Table 5-9 summarizes the results of a survey conducted by California Air Resources Board (ARB) on oil refinery flares. In Table 5-10, the results of a survey on flare applications in the chemical industry is presented. In addition to the references indicated in the tables, other references containing general information on flares were reviewed. These include References 5, 22, 23, 25, 29, 70, 141, 148, and 150.

TABLE 5-8. SUMMARY OF FLARE DATA

Compound	Composition Data[a]	Comments	Control Efficiency[b] (%)	Reference
Acetaldehyde	Y	Absorber emissions are controlled by flares.		10
Acetic acid			95 98.5[c]	11
Acrolein		Various vents are controlled by flares.		11
Acrylic acid	Y	Acrylic acid and acrolein containing streams are flared.		11
Acrylonitrile		A 16-inch flare is used for emergency and shutdown periods. A 6-inch flare is used for controlling emissions from HCN storage tanks. In one plant, various vents are controlled by a flare with a stack consisting of a 24-inch pipe above the ground.		11
Allyl alcohol		Light stripper column vents are flared.		11

TABLE 5-8. (CONTINUED)

Compound	Composition Data[a]	Comments	Control Efficiency[b] (%)	Reference
Allyl chloride		Absorber and distillation column vents are sent to flares.		11
Butadiene		Various column vents are routed to flares.		11
Chloroprene		Butadiene dryer vent is controlled by a flare.	100	11, 31
Cumene		Benzene recovery system vent and distillation column vent are sent to a flare.		8
Cyclohexane		Smokeless flares are used for off-gases from column reboilers.		7
Cyclohexanol/ Cyclohexanone		Scrubber off-gas is sent to a flare.		7
Chloromethanes		At a methyl chloride plant, emergency releases are controlled by flares.		9

TABLE 5-8. (CONTINUED)

Compound	Composition Data[a]	Comments	Control Efficiency[b] (%)	Reference
Ethylbenzene/Styrene	Y	Flares are used for controlling process emissions.		7
Ethylene		Elevated flares and horizontal ground-level flares are used for intermittent and and lube-oil vent emissions. Storage emissions are also flared. In some applications, steam-assisted flares are used.	70	10 10
Ethylene glycol		Uncondensed gases from vent condensers are flared.		10
Ethylene oxide		Process and storage emissions are flared.		10
Formaldehyde				10
Linear alkylbenzenes (LAB)		Vent gases are flared.		8

TABLE 5-8. (CONCLUDED)

Compound	Composition Data[a]	Comments	Control Efficiency[b] (%)	Reference
Methanol		Flares are used only when the purge gases can not be used as fuel.		10
Methyl ethyl ketone (MEK)	Y	Smokeless flares are used for burning vent gases from s-butanol recovery and MEK hydration columns.		11
Methyl methacrylate		Reactor off-gas is sent to a flare.	99+	11
Propylene oxide		Ethylbenzene and styrene emissions are controlled by flares.		11
Vinyl acetate	Y	Emissions of ethylene, ethane, acetaldehyde, acetic acid, and vinyl acetate are controlled by flaring.	100, 100	10

[a] Y indicates that composition data are available and presented in Appendix D.
[b] Efficiencies are reported as VOC destruction. All data are estimated values.
[c] Vendor estimate for acetic acid destruction.

TABLE 5-9. SURVEY OF CALIFORNIA OIL REFINERY FLARES[a] (CALIFORNIA AIR RESOURCE BOARD, 1980)

Refinery	Flare Type	Diameter (in)	Smoke Suppression	Service	Flowrate scf/yr	Fuel	Steam/Fuel
1	Elevated	30	Steam	Emergency	---	---	~0.35
1	Elevated	24	Steam	Emergecy	---	---	~0.35
1	Elevated	24	Steam	Emergency	---	---	~0.35
2	Elevated	--	Steam	Continuous	---	---	---
3	Elevated	30	Steam	Emergency	---	H_2, CO, N_2, C_1-C_3	---
3	Elevated	30	Steam	Emergency	---	---	---
3	Elevated	8	Steam	Emergency	---	---	---
4	Ground	--	Steam	Emergency	---	---	0.40
4	Elevated	30	Steam	Emergency	---	---	0.38
4	Elevated	8	Steam	Emergency	---	C_1, C_4, S	0.30
4	Elevated	10	Steam	Emergency	---	LPG	---
5	Ground	--	Steam	Emergency	180M	---	---
5	Elevated	--	Steam	Emergency	---	---	---
5	Elevated	16	Steam	Emergency	---	---	---
5	Elevated	20	Steam	Emergency	---	---	---
5	Elevated	10	Steam	Emergency	---	---	---
6	Elevated	30	Steam	Emergency	36M	---	---
7	Ground	--	Venturi	Emergency	---	---	---
8	Elevated	8	Steam	Con't & Emer.	---	---	~0.5
9	Elevated	8	Steam	Emergency	50M	H_2, C_2-C_6, H_2O	1.7
9	Elevated	12	Steam	Emergency	3.5M	H_2, C_1-C_6, H_2O	1.7
10	Elevated	--	Steam	Emergency	0.9M	---	0.5
11	Elevated	36	Steam	Emergency	---	---	~0.3
11	Elevated	36	Steam	Emergency	---	---	~0.3
11	Elevated	36	Steam	Emergency	---	---	~0.3
11	Elevated	10	Steam	Emergency	---	---	~0.3
12	Elevated	18	Steam	Emergency	547M	HC, H_2S, RSR	0.3->1
13	Elevated	31	Steam	Emergency	---	HC, H_2S, RSR	0.33
14	Elevated	6	Steam	Con't & Emer.	3.9M	C_1-C_5, H_2	0.43
15	Elevated	48	Steam	Emergency	111	---	0.3-0.4
15	Elevated	48	Steam	Emergency	283	---	0.3-0.4
15	---	30	Forced Draft	Emergency	1.2	---	---
15	Elevated	16	Steam	Emergency	27.6	---	0.2-0.35
16	Elevated	36	Steam	Emergency	---	C_1, C_2, H_2, N_2, H_2, O_2, CO_2	~0.2
16	Elevated	36	Steam	Emergency	---	"	~0.2

TABLE 5-9. SURVEY OF CALIFORNIA OIL REFINERY FLARES (CALIFORNIA AIR RESOURCE BOARD, 1980) (CONTINUED)

Refinery	Flare Type	Diameter (in)	Smoke Suppression	Service	Flowrate scf/yr	Fuel	$\frac{\text{Steam}}{\text{Fuel}}$
16	Ground	--	Steam	Emergency	---	"	~0.2
16	Elevated	36	Steam	Emergency	---	"	~0.2
16	Elevated	36	Steam	Emergency	---	"	~0.2
16	Elevated	42	Steam	Emergency	---	"	~0.2
16	Elevated	42	Steam	Emergency	---	"	~0.2
16	Elevated	48	Steam	Emergency	---	"	~0.2
16	Elevated	--	Steam	Emergency	---	"	~0.2
16	Elevated	70	Steam	Emergency	---	"	~0.2
16	Elevated	--	Steam	Emergency	---	"	~0.2
16	Elevated	--	Steam	Emergency	---	"	~0.2
17	Ground	--	Steam	Emergency	---	"	~0.2
17	Elevated	42/100	Steam	Emergency	---	"	~0.2
17	Elevated	36	Steam	Emergency	---	"	~0.2
17	Elevated	--	Steam	Emergency	---	"	~0.2
17	Elevated	48/72	Steam	Emergency	---	"	~0.2
17	Elevated	12	Steam	Emergency	---	"	~0.2
17	Elevated	12	Steam	Emergency	---	"	~0.2
18	Elevated	--	Steam	Emergency		C_1-C_5, NH_3, CO_2 H_2S	~0.3
18	Elevated	--	Steam	Emergency	10,740		0.3
19	Elevated	42	Steam	Emergency	---	---	~0.3
19	Elevated	36	Steam	Emergency	---	---	~0.3
19	Ground	--	--	Emergency	---	---	0
20	Ground	--	Steam	Emergency	---		---
20	Elevated	--	Steam	Emergency	---		---
20	Elevated	--	Steam	Emergency	---		---
20	Elevated	--	Steam	Emergency	---		---
20	Elevated	--	Venturi	Emergency	---		---
21	Ground	--	Self-Inspiration	Emergency	0.25M	C_1-C_3	0

[a] Reference 149.

TABLE 5-10. SURVEY OF GASES FLARED IN THE CHEMICAL INDUSTRY[a]

Process	Composition					% of Combustible Capacity Flared
	Hydro-Carbcn	CO	H_2	N_2, H_2O CO_2	Other	
Ethylene	100.0	0	0	0	0	0.39
Ethylene	89.3	2.2	3.34	5.16	---	2.75
Ethylene	89.69	---	---	3.6	6.7	1.37
Ethylene	100.0	---	---	---	---	0.49
Ethylene	97.77	---	2.23	---	---	1.18
Ethylene	100.0	---	---	---	---	2.26
Acetylene	98.5	---	---	---	---	0.19
Aromatics	100.0	---	---	---	---	0.38
Petrochemicals	100.0	---	---	---	---	1.75
Petrochemicals	---	---	---	---	---	0.02
Polypropylene	73.4	---	---	26.6	---	7.75
Polypropylene	100.0	---	---	---	---	0.83
Butyl Rubber	100.0	---	---	---	---	6.57
Acetic Acid	100.0	---	---	---	---	2.89
Acetic Acid	10.0	25.0	50.1	15.0	---	22.30
Acetic Anhydride	35.9	45.3	---	18.75	---	3.56
Acetic Anhydride	59.9	26.0	0.26	13.86	---	26.25
Adipic Acid	---	---	---	---	100.0	---
Acrylonitrile	---	---	---	100.0	---	0.0016
Acrylonitrile	---	---	---	100.0	---	0.03
Ammonia	75.0	---	24.95	---	---	3.59
Ammonia	---	---	---	---	100.0	0.01
Ammonia	---	---	---	---	100.0	0.22
Alcohols	100.0	---	---	---	---	2.77
Carbon Black	0.77	6.48	0.62	92.0	0.139	5.61
Phosphorus	0.18	96.84	0.35	2.22	---	42.18
C_2S and S Recovery	81.1	---	---	---	18.9	0.22
NaHS	---	---	---	---	100.0	0.01
Aldicarb	86.1	---	---	---	14.67	2.48
CO for Phosgene	100.0	---	---	---	---	0.75
Oil Additive	100.0	---	---	---	---	1.16
Ethylene Loading	100.0	---	---	---	---	0.50
Ethylene Storage	100.0	---	---	---	---	0.28
Butadiene Storage	90.9	---	---	---	---	74.9
Ammonia Storage	---	---	---	---	100.0	0.87
HCN Storage	---	---	---	---	100.0	87.6
Tank Car Loading	90.0	---	---	10.0	---	---
Agodrin	100.0	---	---	---	---	0.29
Nudrin	46.9	---	---	21.9	31.25	0.19
Nudrin	---	---	---	75.0	25.0	0.04

[a] Reference 149.

As pointed out in Reference 70, there are little data on control efficiencies achieved by flares. In the absence of direct emissions measurements on operating flare flames, measurements have been made on pilot scale and small commercial flare heads. Table 5-11 summarizes these data. Recently combustion efficiencies were measured for a wide variety of operating conditions typical of commercial flares. The test conditions and the measured efficiencies are presented in Table 5-12.

No information was found in the references on actual flare costs. However, general cost data based on design considerations are available in References 5, 22, and 23.

5.1.1.4 Boilers/Process Heaters--

Introduction--Fireboxes of boilers and fired heaters can be useful as emission control devices if the temperature, turbulence, and residence time are adequate to burn the combustible contaminants.[22] In addition, the waste gas stream must have a sufficiently high heating value to be used as part of the fuel input to the combustion device.[5] Furthermore, the off-gas volume flow should not be large enough to upset the combustion process in the boiler or heater. Waste streams with large flows and low heating values can adversely affect the operation of the combustion device.[125] By lowering furnace temperatures, they can cause incomplete combustion and reduce stream production. For the combuster to serve as an effective control device, the firing cycle of the combustion device must coincide with the operation of the pollution source generating the waste stream.

Summary--Information on use of boilers and process heaters as emission control devices is presented in Table 5-13. This information is based on a review of the references indicated in the table. Other references reviewed include References 5, 6, and 125.

TABLE 5-11. COMBUSTION EFFICIENCY OF FLARE FLAMES[a]

Study	Flare Size (in)	Design	Velocity (ft/sec)	Gas Flared	Measured Efficiency (%)
Palmer (1.10)	0.5	Experimental Nozzle	50-250	Ethylene	>97.8
Lee & Whipple (1.11)	2.0	Holes in 2" Cap	1.8	Propane	96-100
Siegel (1.12)	27 [b]	Commercial Flare gas Coanda FS-6	0.7-16	Refinery Gas[c]	97->99
Howes, et al (1.8)	6 [d]	Commercial Air Assist. Zink LH	40-60	Propane	92-100
Howes, et al (1.8)	3 at 4[e]	Commercial H.P. Zink LRGO	Near Sonic (estimate)	Natural Gas	>99
McDaniel (1.13)	8	Commercial Zink STF-S-8	0.03-62	Propylene/Nitrogen[f]	67-100
McDaniel (1.13)	6[d]	Commercial Air Assist. Zink STF-LH-457-5	1.4-218	Propylene/Nitrogen[g]	55-100

[a] Reference 148.
[b] Opening of a cone on an FS-6 Coanda flare head.
[c] 50 percent hydrogen plus light hydrocarbons.
[d] Supplied through spiders; high Btu gas through area of 5.30 in^2 and low Btu gas through 11.24 in^2.
[e] Three Spiders, each with an open area of 1.3 in^2.
[f] Heating value was varied from 209 to 2,183 Btu/scf.
[g] Heating value was varied from 83 to 2,183 Btu/scf.

TABLE 5-12. COMBUSTION EFFICIENCIES OF VARIOUS FLARE HEADS (%)[a]

Gas[b]	3-in[c,d] EER	3-in. EER Hi-Vel[e]	6-in. EER	12-in. EER	12-in.[f] Indus A	12-in.[f] Indus B	12-in.[f] Indus C
100% Propane	--	99.74 99.87	--	--	--	--	--
77% Propane	--	99.73 99.88	--	--	--	--	--
56% Propane	98.37-98.95	97.27-99.33	98.47-99.76	98.29-99.50	99.12-99.78	99.48-99.65	99.08 99.65
50% Propane	--	99.72 99.87	--	--	--	--	--
Low-Btu (<5% Propane)[g]	90.19-99.92[g]	--	92.24-99.36	94.89-99.73	98.49-	99.21-99.72	91.16 99.52

[a] Reference 148.

[b] Propane/nitrogen mixture.

[c] Flare head diameter.

[d] Flare head fabricated by Energy and Environmental Research Corp.

[e] Flare exit velocity up to 428 ft/sec.

[f] Commercial flare heads supplied by three flare manufacturers = A, B, and C.

[g] Btu content as low as 270 Btu/scf.

TABLE 5-13. APPLICATIONS OF BOILERS/PROCESS HEATERS AS CONTROL DEVICES

Compound	Composition Data[a]	Comments	Reference
Acetic anhydride	Y	Reactor gases are burned in tne pyrolysis furnace. Estimated control efficiency is 100 percent.	11
Acetone/Phenol		Column vents are sent to boilers.	8
Adipic acid		Off-gas from absorber is sent to a steam boiler.	7
Butadiene		Methyl and vinyl acetylene are burned in a steam boiler.	11
Caprolactam		Dehydrogenation vent stream is used as fuel.	7
Cumene		Various vents are sent to the plant fuel gas manifold.	8
Cyclohexane		Various waste streams are used as fuel gas.	7
Cyclohexanol/ Cyclohexanone		Scrubber off-gas is burned in a boiler.	7
Dimethyl terephthalate		Recovery still vents are routed to a boiler.	8
Ethylbenzene/Styrene	Y	Off-gases are sent to a process heater. Reactor off-gases are burned in a boiler.	7
Ethylene oxide	Y	Waste gases with high hydrocarbon concentration are sent to boilers.	10

TABLE 5-13. APPLICATIONS OF BOILERS/PROCESS HEATERS AS CONTROL DEVICES (CONCLUDED)

Compound	Composition Data[a]	Comments	Reference
Formaldehyde			10
Linear alkylbenzenes		Refining column vents are routed to a process heater.	8
Methanol	Y	Waste gases are burned as fuel in a boiler or reformer.	10
Propylene oxide		Waste stream containing t-butanol and other hydrocarbons is used as supplementary fuel.	11

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[a] Y indicates that composition data are available and can be found in Appendix B.

As the information in Table 5-13 and the composition data that are available for some waste streams indicate, this method of controlling emissions is employed for a variety of compounds. In general, waste streams are burned in boilers or process heaters as supplemental fuel only if they have sufficient heating value.[7,10,11] For streams with high heating value such as waste streams from formaldehyde or ethylbenzene/styrene manufacturing, the process off-gas is the main fuel to the process heater or boiler.

Data on type, operation, and cost of boilers and process heaters used for controlling emissions are not available in the data base. However, information on generalized cost estimates for process heaters and boilers are available from studies on air oxidation, distillation, ethylbenzene/styrene, and reactor processes.

5.1.2 Adsorption

5.1.2.1 Introduction--

Vapor-phase adsorption is currently used by many industries as an emission control or solvent recovery technique.[6] As a control technique, it is used for waste streams of low VOC concentrations, when condensers or scrubbers are ineffective or uneconomical.[6]

Adsorption is a process whereby hydrocarbons and other compounds are selectively adsorbed on the surface of such materials on silica gel and activated carbon as well as natural and synthetic zeolites. Carbon has the largest affinity for organic compounds and is widely used for pollution control.[28,147]

Adsorption can be carried out in batches in fixed beds or continuously in fluidized beds. Fixed bed adsorption is usually a batch operation involving two main steps, adsorption and regeneration.[6,22,28,132] When the VOC-laden waste gas is passed through the carbon bed, adsorption of the organic vapor takes place. As the adsorptive capacity of the bed is approached, traces of vapor appear in the exit gas indicating that the breakthrough point of the carbon bed has been reached. At this point, the waste gas is routed to a fresh carbon bed while the saturated bed is regenerated by passing a hot inert gas, usually low-pressure steam, through it to desorb the organics. The steam and organic vapors leaving the bed are condensed, and the organic layer is separated from the water by decantation or distillation.

In fluidized bed adsorption, the system consists of a multistage and countercurrent fluidized bed adsorption section and a moving bed desorption or regeneration section. In the adsorption section, the fresh carbon is introduced at the type of the adsorption column and flows down a series of trays while the exhaust gases enter at the bottom of the column and flow upward, exiting from the top tray. Since the carbon is continuously removed from the bottom tray, no breakthrough occurs.

The carbon leaving the adsorption section falls into the regeneration or desorption section which is a moving packed bed. The hydrocarbons are desorbed from the bed by passing a hot inert gas through the bed or by direct steaming of the bed. Regenerated carbon is drawn off at the bottom and conveyed to the top of the adsorption section.

The quantities of organic vapors adsorbed on an adsorbent are a function of the particular vapor in question, the adsorbent, the adsorbent temperature, and the vapor concentration.[29] Removal of organic vapors by adsorption is practical for gases with molecular weights over 45.[25,29] Low molecular weight compounds do not adsorb well on carbon. For high molecular weight compounds (>130), this method is not practical because these compounds are difficult to desorb during regeneration.[125] During adsorption of multicomponent gas streams, the high-boiling components may displace the low-boiling components.[28,29]

At a given temperature, the amount of vapor adsorbed on an adsorbent for a particular concentration in the gas stream is generally expressed as an adsorption isotherm. The quantity of vapor adsorbed is a function of temperature and vapor concentration. This quantity increases when the adsorbent temperature decreases. It also increases when the vapor concentration increases.[29]

Since adsorption is an exothermic reaction, heat is released during the process. This may cause the bed temperature to rise and decrease the efficiency of the control technique.[125] It may even create a fire hazard. Therefore, inlet concentrations may be limited to 25 percent of LEL.[6]

Although some moisture is desirable in the waste gas to provide uniform bed temperatures, excessive humidity can adversely affect the pollutant removal efficiency of a carbon adsorption system. The water vapor in the gas stream can rapidly saturate the bed, taking up adsorption sites. Operating capacity decrease becomes important at relative humidities over 50 percent.[125] Some reactions produce tar-like products that condense at the operating temperatures of carbon adsorbers. These products can not be easily desorbed, hence they can cause fouling of the bed.

5.1.2.2 Summary--

In Table 5-14, information on industrial applications of carbon adsorption as a control technique is summarized. The data were gathered from the five references indicated in the table. In addition, References 6, 22, 25, 28, 29, 132, and 143 containing general information on adsorption were reviewed.

Table 5-14 summarizes the emission control information for SOCMI emissions and for emissions resulting from solvent use in operations such as graphic arts and surface coating. From the table, it appears that carbon adsorption has been applied predominantly to chlorinated compounds, alcohols, ketones, and aromatic compounds.

TABLE 5-14. SUMMARY OF CARBON ADSORPTION DATA

Compound	Flowrate (cfm)	Control Efficiency (%)	Comments	References
Acetone/Phenol		92	Overall hydrocarbon removal efficiency.	8
		83.4	Efficiency calculated from design data.	
		99	Efficiency including condenser.	
Acrylonitrile			Used for controlling storage emissions.	117
Adipic acid				117
Aniline				117
Benzene			Used for controlling storage and fugitive emissions.	60, 117
Carbon tetrachloride				117
Chlorobenzene				7, 117
Chloroform			Used for controlling storage emissions.	117
Cyclohexane				117
Diethanolamine			Used for controlling storage emissions.	117
Dimethyl terephthalate[a]	10,000	80	VOC removal efficiency	8, 117
		97	p-Xylene removal efficiency.	
Ethylene dichloride	16,020		The waste stream also includes acetylenes.	117
Maleic anhydride	43,000	85	System control efficiency.	7, 117
Methanol				117
Methyl chloride				117
Methylene chloride		>90	Reported efficiency for controlling emissions from pharmaceutical manufacturing.	60, 117
Methyl chloroform				117
Methyl ethyl ketone			Used for controlling storage emissions.	117
Methyl methacrylate			Used for controlling storage emissions.	117
Naphthalene				117
Perchloroethylene		96, 99,	Perchloroethylene control efficiency.	153
		97, 97	Test data from dry cleaning industry.	
Phosgene				117
Styrene			Used for controlling storage emissions.	117
Terephthalic acid				8, 117
Toluene			Used for controlling storage emissions.	117
Toluene Diisocyanate				117
Trichloroethylene				117
Vinyl chloride (VCM)			The source of emissions is PVC manufacturing. The outlet gas concentration is reduced to ≤5 ppm. Pilot test data indicate 99.0% VCM reduction.	60, 58
Vinylidene chloride			Used for controlling storage emissions.	117
Xylene				117

[a] Cost data for two adsorption units:
Installed capital cost: $1.05/M lb of product (1972 dollars).
Annual operating cost: $0.55/M lb of product (1977 dollars).

Cost data have been identified for carbon adsorption systems at a dimethyl terephthalate manufacturing facility as shown in Table 5-14. Generalized cost data based on design considerations are available in References 6, 21, 22, 23, 28, 132, and 147.

5.1.3 Absorption

5.1.3.1 Introduction--

Absorption is a process in which one or more components of a gas mixture are selectively transferred into a relatively nonvolatile liquid.[28,125] It is one of the primary methods of product and/or raw material recovery. Absorption may be physical when the gaseous compound simply dissolves in the absorbent. Chemical absorption occurs when there is a reaction between the gaseous component and the absorbent.[15] Common absorbents are water, mineral oils, nonvolatile hydrocarbon oils, and aqueous solutions of sodium hydroxide and sodium carbonate.[125] Water may be used for absorption of organic compounds that are readily soluble in water such as alcohols, organic acids, aldehydes, ketones, amines and glycols.[6]

Absorption is increased by lower temperatures, higher solubility and higher gas concentrations, higher liquid-to-gas ratios, and a greater contacting surface.[28,132] Low concentrations require long contact times and large quantities of absorbent for adequate emissions control. Therefore, absorption is an efficient control technique only when the pollutant concentrations are high.[132] It is usually not considered effective when the concentrations are below 200-300 ppmv.[6] However, excessive concentrations can raise the temperature of the absorption tower by increasing the amount of heat released through dissolution and lower the removal efficiency of the absorber.

When organic liquids are used as absorbents, stripping and recycling of the liquid to the absorber are common practices. In such cases, the removal efficiency is dependent on the solvent stripping efficiency.[125] Alternatively, the scrubbing liquid can be recycled to the process.[8]

As emission control devices, absorbers can be used separately or in combination with other control devices such as incinerators.[22,125] The types of equipment that are commonly used for gas-liquid contact operations include packed towers, plate or tray towers, spray chambers, venturi absorbers, and vessels with sparging equipment.[6] The use of venturi scrubbers, spray chambers, and sparging is generally limited to the control of particulate matter and highly soluble gases.[6,125]

5.1.3.2 Summary--

Table 5-15 summarizes information on the use of absorption as an emission control technique. Much of the data is concentrated in the SOCMI area. The information is based on review of the references indicated in the table. In addition to these references, other references containing general information on absorption were reviewed (References 6, 22, 23, 25, 28, 29, and 132).

As Table 5-15 indicates, absorption as an emission control technique has been applied to several types of compounds including aromatics, chlorinated compounds, fluorinated compounds, alcohols, acids, substituted aromatics, aldehydes, and esters.

Review of the references indicates that absorbers are often used as product/raw material recovery units and hence are not considered to be emission control devices. In some cases, absorbers are used as auxiliary control devices in combination with condensers and thermal oxidizers. Water appears to be the most commonly used absorbent. However, oils, dilute acids, and other organic solvents also are used.

Cost information has been identified for absorption systems used in chloroprene and terephthalic acid/dimethyl terephthalate manufacturing as shown in Table 5-15. Generalized cost data for absorption systems based on design considerations are available in References 6, 22, and 23.

TABLE 5-15. SUMMARY OF ABSORPTION DATA

Compound	Scrubbing Liquid	Accompanying Control Device	Control Efficiency[a] (%)	Reference
Acetaldehyde[b]	Water			10
Acetic acid	Chilled methanol		80	11
	Water and acetic acid		99	
Acetone/Phenol	Water	Condenser	96, 93	8
			70	
Acrylonitrile[c]	Water		99	11
Acrylic acid				11
Allyl alcohol				11
Allyl chloride				11
Aniline	Dilute sulfuric acid[d]		99.9	10
	Water			
Benzene[e]				2
Butadiene[f]				11, 125
Caprolactam				7
Carbon tetrachloride/ Perchloroethylene	Caustic			9
Chlorobenzene	Water			7
	Caustic			
Chloromethanes	Caustic			9
Chloroprene	Oil		100[g]	11, 31, 62
	Water	Condenser	96.5[g]	
	Caustic			
	Oil	Condenser	90[g,h]	
Chloroprene/Neoprene	Oil	Condenser	97[g,i]	31, 62
Cyclohexanol/Cyclohexanone[j]	Oil		99	7, 125
Epichlorohydrine				11
Ethylbenzene/Styrene				7
Ethylene dichloride	Water			9
	Hydrocarbon			
Ethylene oxide[k]				10
Flurocarbons	CCl_4			9
Formaldehyde			74	10
	Water		94[l]	
Maleic anhydride			50	7
Methanol[m]	Water			10
Methyl chloroform	Water		90	9
Methyl ethyl ketone	Water			11
Nitrobenzene	Nitrobenzene		99.9	8
	Water			
Perchloroethylene/ Trichloroethylene	Water[o]		90	9
		Thermal oxidizer	98	

TABLE 5-15. SUMMARY OF ABSORPTION DATA (CONTINUED)

Compound	Scrubbing Liquid	Accompanying Control Device	Control Efficiency[a] (%)	Reference
Phosgene				8
Phthalic anhydride		Thermal oxidizer	96	
		Thermal oxidizer	96[p], 96.5[p]	97, 131, 145
Propylene oxide	Water[q]			11
Terephthalic acid/ Dimethyl Terephthalate	Water		95.6[r]	8
	Chilled solvent[s]		99	
	Xylene[t]		97	
	Methanol			
Toluene diisocyanate	Water[u]		60[v]	8
	Caustic[u]		99[v]	
	Water[w]		98[v]	
Vinylidene chloride	Water		90	9
		Thermal oxidizer	97	
Xylene				8

[a] Efficiency based on VOC concentration.
[b] Scrubbers are used for product recovery.
[c] Used for controlling acetonitrile and acrylonitrile storage emissions.
[d] Scrubbers are used for process and storage emissions.
[e] Absorbers are used for controlling emissions from processes other than production.
[f] Scrubbers are used for product/raw material recovery.
[g] Efficiency for hydrocarbon removal.
[h] Efficiency including condensation is 99.5 percent. The absorber is a two-stage spray tower. Operating data: Flowrate = 36 lb/hr; T = 65°F; Inlet concentration = 86 percent HC.
[i] Efficiency including condensation is 98.4 percent. The absorber is a five-stage spray tower. Operating data: Flowrate = 187 lb/hr, T = 45°F; Inlet concentration = 39 percent HC. Installed capital cost based on 1974 dollars is $30,000.
[j] Absorbers are considered part of the process equipment.
[k] Scrubbers are used for controlling storage emissions.
[l] The performance of the scrubber is hampered by the insoluble nature of dimethyl ether in the gas stream.
[m] Scrubbers are used for controlling methanol emissions from storage tanks.
[n] Scrubbers are used for controlling benzene emissions.
[o] Scrubbers are used for controlling storage emissions.
[p] Total organics removal.
[q] Packed column aqueous scrubbers are used.
[r] Efficiency is reported for acetic acid removal.
[s] The absorber is used for methanol recovery. The installed capital cost based on 1972 dollars is 0.61 $/M lb of product. The annual operating cost based on 1977 dollars is 0.32 $/M lb of product.
[t] The installed capital cost is 0.21 $/M lb of product based on 1972 dollars. The annual operating cost is 0.11 $/M of product based on 1977 dollars.
[u] The scrubber is a spray tower.
[v] Estimate efficiency based on data.
[w] A packed scrubber is used for phosgene removal.

5.1.4 Condensation

5.1.4.1 Introduction--

Condensation occurs when the partial pressure of a condensible component is equal to its vapor pressure at that temperature.[22,25,125] Any component of a vapor mixture can be condensed if it is brought to equilibrium at a low enough temperature.[6,28] This condition can be achieved by increasing the system pressure at a given temperature or reducing the temperature at constant pressure.

Condensation is one of the primary methods of product recovery. As emission control devices, condensers are often used as auxiliary control devices before absorbers, incinerators or absorbers.[6,22,125] Any existing condenser can be modified for improved emission control by operating it at lower temperatures.[125] Condensation devices are usually either surface or contact condensers. Most surface condensers are of the shell-tube type. The coolant used in the condenser depends on the saturation temperature of the volatile organic compound. Chilled water can be used down to 45°F, brines to -30°F, and chlorofluorocarbons below -30°F.[125] In contact condensers, a cooled liquid such as water or a process feed stream is sprayed directly into the gas stream. This type of condenser also acts as a scrubber in removing noncondensible vapors.[125]

Gas flowrates from 100 to 2,000 cfm are representative of the capacity range for condensers as emission control devices.[125] Vent streams containing less than one-half percent organics are generally not considered for control by condensation. For waste streams where concentrations are typically below 25 percent of the LEL, condensation is very difficult. In some applications, the concentration of the organic compound can be increased by compressing the process gas stream. Then condensation can take place at a higher temperature.[28]

5.1.4.2 Summary--

Information on use of condensation as a control technique is summarized in Table 5-16. This summary is based on a review of the references indicated in the table. In addition, References 6, 22, 23, 25, 28, and 132 were also reviewed. Much of the data is concentrated in the SOCMI area.

A review of the literature indicates that condensation is widely employed either as a product/raw material recovery technique or as an emission control method. In some cases, condensers have been used as auxiliary control devices in conjunction with scrubbers and carbon adsorbers.[8,9,11,125]

Refrigerated condensers are commonly used for controlling process and storage emissions. Coolants used in condensation processes are air, water, and brine.[11] In general, the applicability of condensation as an emission control technique is limited by the available cooling source.

Control efficiencies observed for condensers, based on the literature search, range from 25 to 99.8 percent. Most of the efficiency data lies in the 60-99.8 percent range.

Generalized cost data for condenser systems based on general design considerations are available in References 6, 22, 23, and 147.

5.2 PARTICULATE EMISSION CONTROLS

Particulate emissions are generally controlled by ESP's, baghouses, wet scrubbers, and cyclones. The operating principles of these devices are quite different than those used in gaseous pollutant control. Therefore, the former will be discussed separately in this section.

TABLE 5-16. SUMMARY OF CONDENSATION DATA

Compound	Flow Rate (lb/hr)	Accompanying Control Device	Control Efficiency[a] (%)	Comments	References
Acetaldehyde					10
Acetic acid			68, 60	Refrigerated condensers are used.	11, 125
			99[b]	A water-cooled vent condenser is used.	
Acetone/Phenol		Scrubber	96, 95, 93, 84, 95		8, 125
			90	Refrigerated condenser at 40°F and 8.5 psig is used.	
		Carbon adsorber	99		
Acrylic acid			75[c]		11, 125
Acrylonitrile				Refrigerated condensers are used.	11, 125
Allyl alcohol					11
Allyl chloride					11
Aniline			96		10
Benzene					2, 14
Butadiene					11, 125
Caprolactam			90, 70		7
Carbon tetrachloride			60-80[d]	Refrigerated condensers are used.	9
Cumene					8
Chlorobenzene					7
Chloroform			66[d]		9
Chloroprene	331		81[e]	Brine cooling at -2°F (shell and tube heat exchanger). Inlet concentration is 48 wt % hydrocarbon. Energy requirement for condensation is 22,000 btu/hr.	11, 31, 62
	542	Scrubber (oil)	95[e, f]	Brine cooling at -2°F, (shell and tube heat exchanger). Energy requirement for condensation is 93,000 btu/hr.	
			89[e, g]	Water quench cooling.	
			28[e, g]	Brine cooling at 0°F.	
			95.6[e], 94[e], 50[e]	Brine cooling at 0°F.	
			81[e]	Brine cooling.	

TABLE 5-16. SUMMARY OF CONDENSATION DATA (CONTINUED)

Compound	Flow Rate (lb/hr)	Accompanying Control Device	Control Efficiency^a (%)	Comments	References
Chloroprene/Neoprene	2,875		99.8^e	Brine cooling at -2°F (shell and tube heat exchanger). Inlet concentration = 40 wt % hydrocarbon. Energy requirement for condensation is 1,200,000 btu/hr.	31, 62
	32,000		99.995^e	Direct-contact cooling with water at 40-75°F. Inlet concentration = 48 wt % hydrocarbon. Energy requirement for condensation is 10,000 btu/hr for steady state and 3,000,000 btu/hr for heat sink/dump.	
	275	Scrubber (oil)	$43^{e,h}$	Direct-contact cooling with water at 36°F. Inlet concentration = 46 wt %. Energy requirement for condensation is 110,000 btu/hr.	
			95.6^e, 99.9^e 68^e	Brine cooling at 0°F. Brine cooling at 32°F.	
Chloromethanes			50	Refrigerated and water cooled condensers are used.	9
Dimethyl terephthalate			91		8
Ethylbenzene/Styrene					7
Ethylene dichloride				Refrigerated condensers are used.	8, 125
Ethylene oxide					125
Ethylene glycol				Contact and surface condensers are used. An air-cooled condenser is also used.	10
Flurocarbons		Scrubber(CCl_4)	86.3^i, 83.5, 99^j	A condenser with -5°F brine coolant is used.	9
			75^k, 25^l	Refrigerated condensers are used.	
			80^m, 76^k	Refrigerated condensers are used.	
Formaldehyde			96.1 80	Refrigerated condenser is used. Refrigerated condenser using water at 35°F is used.	10
Linear alkylbenzenes				Surface condensers and refrigerated condensers are used.	8
Methyl chloroform					9
Methylene chloride		Carbon adsorber		Water-cooled condenser is used	60

TABLE 5-16. SUMMARY OF CONDENSATION DATA (CONTINUED)

Compound	Flow Rate (lb/hr)	Accompanying Control Device	Control Efficiency[a] (%)	Comments	References
Methyl methacrylate			96.7, 90		11
Nitrobenzene				Benzene-contaminated strems are controlled by condensers.	8
Perchloroethylene/ Trichloroethylene			80 50-99, 85	A chilled water condenser is used. Storage emissions control efficiency. Refrigerated condensers are used on storage tank vents.	9
Toluene					32
Toluene diisocyanate			97, 97	Estimated efficiencies based on data. Water cooled surface condensers are used.	8
Vinylidene chloride			93	Refrigerated condenser is used.	9
Xylene					8

[a] Control efficiency is in terms of VOC concentration unless otherwise noted.
[b] n-Propyl acetate removal efficiency.
[c] Removal of organics.
[d] Storage emission control efficiency.
[e] Hydrocarbon removal efficiency.
[f] Efficiency including absorption is 99.5%.
[g] Combined efficiency for these two systems is 92%.
[h] System efficiency including absorption is 98.4%. Efficiency for absorption step is 97%.
[i] Fluorocarbon removal efficiency.
[j] F-12 (dichlorodifluoromethane) removal efficiency.
[k] F-22 (chlorodifluoromethane) removal efficiency.
[l] The low efficiency results from the fact that the refrigerated condenser is designed to recover F-22 from the F-22 distillation column.
[m] F-23 and VOC removal efficiency.

The literature summarized in this section contains control information pertaining to particulate emissions from combustion, metal processing, and SOCMI source categories. For combustion and metal processing categories, only Radian in-house information sources were reviewed. Metals emitted from these categories that are included in this study are cadmium, chromium, copper, manganese, nickel, and zinc.

Only five compounds from the SOCMI source category are identified as being emitted as particulates. These include adipic acid, caprolactam, dimethyl terephthalate, phthalic anhydride, and terephthalic acid.

Metal emissions are commonly controlled by ESP's, baghouses, cyclones, and wet scrubbers. Cyclones are generally used as pre-cleaning devices for removing larger particles. Available data show that control efficiencies obtained with ESP's and baghouses generally are very high. For example, reported fabric filter efficiencies for particulate emissions are greater than 97 percent. Fabric filter removal efficiencies in excess of 99 percent are reported for metals.

5.2.1 Electrostatic Precipitators (ESP's)

5.2.1.1 Introduction--

The operation of an ESP for removing particulate matter from gas streams involves three steps: (1) electrically charging the particles, (2) establishing an electric field to drive the charged particles to a collection electrode, and (3) removing the collected particles from the collection electrode for disposal.[73]

ESP's are normally used when the larger portion of the particulate matter to be collected is smaller than 20 microns in diameter.[50] When particles are large, cyclones may be employed as precleaners. Gas volumes handled normally range from 50,000 to 2 million ft^3 per minute; operating temperatures range from ambient air temperatures to 750°F.[50]

The efficiency of an ESP for removing particulate matter from a gas stream depends on several factors. The major particulate matter characteristics affecting removal efficiency are electrical resistivity and particle size. Other parameters include volume of gas to be treated, gas velocity, and collection area.

5.2.1.2 Summary--

Table 5-17 summarizes information on use of ESP's as hazardous emission control devices. This information is based on a review of the references listed in the table. References 24 and 50 containing general information on ESP's were also reviewed.

From the literature review, the pollutants that are controlled by ESP's include the metals arsenic, cadmium, chromium, copper, manganese, nickel, and zinc. These pollutants are primarily emitted by fossil fuel combustion and metal processing industries. ESP's are not applicable to organics due to fire problems.

A large proportion of the control efficiency data summarized in the table is from fossil fuel combustion source category because a significant amount of data are available from tests conducted on boilers.[73]

In some cases, ESP's are accompanied by other control devices such as cyclones and spray chambers. In metal processing industries, ESP's are also used as product recovery devices.

Generalized cost data for ESP's based on design considerations can be found in References 21, 23, 49, 50, and 73. Similar information is also reported in several of the EPA's Background Information Documents.

TABLE 5-17. SUMMARY OF INFORMATION OF ESP's

Compound Metal	Accompanying Control Device	Control Efficiency[a] (%)	Source of Emissions	Referen
Cadmium		98 (Cd), 98.8 (Cd)	Fossil fuel combustion	77
		99.6 (Cd), 99.3 (Cd)	Fossil fuel combustion	
		97.8 (Cd), 99.3 (Cd)	Fossil fuel combustion	
		95.5 (Cd), 91.2 (Cd)	Fossil fuel combustion	
		96 (Cd)	Primary copper smelting	
		96.7, 96.7	Primary copper smelting	
		19, 96.5	Primary copper smelting	
Chromium		96.2 (Cr), 99.8 (Cr)	Fossil fuel combustion	75
		98.6 (Cr), 99.8 (Cr)	Fossil fuel combustion	
		98.7 (Cr), 97.0 (Cr)	Fossil fuel combustion	
		97.6 (Cr), 99.1 (Cr)	Fossil fuel combustion	
		85.6 (Cr)	Fossil fuel combustion	
			Steel manufacturing	
Copper		19, 96.5	Primary copper smelting	
		96.7, 96.7	Primary copper smelting	
Manganese		96-98 (Mn)	Steel production	49, 73
		94.2 (Mn), 99.2 (Mn)	Fossil fuel combustion	
		100 (Mn), 94.4 (Mn)	Fossil fuel combustion	
		66.0 (Mn), 98.2 (Mn)	Fossil fuel combustion	
		99.3 (Mn), 98.6 (Mn)	Fossil fuel combustion	
		98.4 (Mn)	Fossil fuel combustion	
Nickel			Primary nickel smelting	73, 74
			Secondary metals recovery	
		96.3 (Ni), 99.4 (Ni)	Fossil fuel combustion	
		99.7 (Ni), 99.8 (Ni)	Fossil fuel combustion	
		98.0 (Ni), 96.4 (Ni)	Fossil fuel combustion	
		98.7 (Ni), 78.5 (Ni)	Fossil fuel combustion	
		100 (Ni)	Ferrous metals production	
		95 (Ni)	Cement production	
	Cyclone	97.5 (Ni)	Cement production	
Zinc			Primary zinc smelting	77
			Primary copper smelting	
	Spray chamber		Primary copper smelting	

[a] In terms of total particulate emissions unless otherwise noted.

5.2.2 Fabric Filters

5.2.2.1 Introduction--

Fabric filters are capable of a high collection efficiency for particles as small as 0.1-0.5 microns.[50,73] Particles entrained in the gas stream adhere to the filter medium as the gas stream flows through the filter. As the dust builds up, the deposit of collected particles (i.e., the filter cake) becomes the filter medium. There are two primary mechanisms for particulate removal: inertial impaction, in which large particles are intercepted by the filter fibers, and diffusion, in which very small particles move toward the filter fibers by Brownian motion.[73] The filter bags are cleaned by one or more of three basic methods: reverse air cleaning, shaking, and pulse cleaning.[73]

Fabric filters permit reuse of collected material and can collect combustible or explosive dusts. They are not sensitive to electrical properties of the particulate matter in the gas stream. However, they have temperature limitations and are sensitive to process conditions. Gas dew point, temperature, flow rate, particle size distribution, inlet gas loading, fabric type, and air-to-cloth ratios are some of the parameters that influence collection efficiencies of fabric filters.[50]

5.2.2.2 Summary--

The information on fabric filter applications as emission control devices is presented in Table 5-18. This information is based on the review of the references indicated in the table. In addition, References 24, 50, and 73 were reviewed. These references contain general information on fabric filter operation, design, and applications.

From the literature review, fabric filters have been used for controlling particulate matter emissions including metals and organic compounds. The metals that are found to be controlled by fabric filters include arsenic, cadmium, chromium, copper, lead, manganese, nickel, zinc,

TABLE 5-18. SUMMARY OF INFORMATION ON FABRIC FILTERS

Compound or Metal	Accompanying Control Device	Control Efficiency[a] (%)	Source of Emissions	Reference
Adipic acid				7
Cadmium		99.0, 99.9, 99.0	Primary zinc smelting	73, 77
		99, 99, 99, 99	Primary lead smelting	
		99, 99	Primary lead smelting	
	Scrubber	99[b]	Primary lead smelting	
	Scrubber	99.95[b](Cd)	Secondary lead smelting	156
Caprolactam				7
Chromium		99,94 (Cr), 99.7 (Cr)	Coal and oil combustion	73, 77
		99.8 (Cr)	Coal and oil combustion	
		99.9 (Cr)	Steel manufacturing	
Copper				77
Dimethyl terephthalate[c]				8
Manganese		99	Iron and steel foundries	49, 73
		98	Ferroalloy production	
		99	Dry cell battery production	
		97.2, 98.5	Steel production	
		99.94 (Mn), 99.78 (Mn)	Fossil fuel combustion	
Nickel			Primary nickel smelting	73, 74
		99.5, 97, 97, 99	Nickel matte refining	
		99, 97, 99, 99.8	Nickel matte refining	
			Second metals recovery	
			Nickel alloy production	
			Ferrous metals production	
		99.8	Cement production	
		99.5 (Ni), 100 (Ni)	Coal and oil combustion	
Terephthalic acid				8
Zinc	Thermal incinerator	99.24[b]	Secondary zinc smelting	77, 84
			Primary zinc smelting	

[a] In terms of total particulate emissions unless otherwise noted.
[b] Combined efficiency.
[c] Available cost data: Installed capital cost: 0.47 $/M lb of product (1973 dollars)
Annual operating cost: 0.16 $/M lb/ of product (year not known).

and zinc oxide. Adipic acid, caprolactam, dimethyl terephthalate, and terephthalic acid are the organic compounds whose particulate emissions are controlled by fabric filters.

In general, these devices are used for controlling emissions from fossil fuel combustion, primary and secondary metals smelting, SOCMI, steel, ferroalloy, and cement manufacturing. Fabric filters are also used for product recovery in several industries. In some cases, fabric filters have been used in combination with other control devices such as scrubbers and after burners.

A large proportion of the control efficiency data for fabric filters is reported in terms of total particulate emissions reduction. The average based on 25 data points in the table is 98.8 percent. Compound-specific control efficiencies are available for chromium, manganese, and nickel.

Actual cost data for fabric filters have been identified for dimethyl terephthalate as indicated in the table. Design and cost of fabric filters are not expected to vary significantly with the pollutants. Generalized cost data for fabric filters based on design considerations are included in References 21, 23, 49, 50, and 73. Similar information is also available in several EPA Background Information Documents.

5.2.3 Wet Scrubbers

5.2.3.1 Introduction--

Wet scrubbers use a liquid, usually water, to remove particulate matter directly from the gas stream by contact or to increase collection efficiency by preventing re-entrainment.[50]

Wet collectors can increase particle removal efficiency in two ways: (1) fine particles are 'conditioned' so that their effective size is increased, and (2) reentrainment of the collected particles is reduced by trapping them in a liquid film.[50] The effective size of the particles can be increased by promoting condensation on fine particles. Trapping of dust particles on liquid droplets is usually accomplished by impact using mechanisms such as gravitational force, diffusion, impingement, or thermal gradients.

In general, particle size distribution, gas temperature and humidity, inlet dust loading, and operating conditions such as contact time and liquid-to-gas ratio determine the collection efficiency.

Common wet scrubber designs include spray towers, venturi scrubbers, and packed-bed scrubbers.

5.2.3.2 Summary--

In Table 5-19, the information on use of wet scrubbers as emission control devices is presented. The data have been gathered from the review of the references indicated in the table. In addition, References 24 and 50 were reviewed for general information on wet scrubbers.

The review of the literature indicates that wet scrubbers are used for controlling particulate emissions of metals and organic compounds. The major source categories emitting the metals cadmium, chromium, manganese, nickel, and zinc are coal and oil combustion and metal processing. The organic compounds adipic acid, chlorobenzene, dimethyl terephthalate, phthalic anhydride, and toluene diisocyanate are primarily emitted from the SOCMI category.

Much of the data are for metal emissions from coal and oil combustion sources where compound-specific control efficiency information is available. The control efficiency data from metal processing sources are reported in terms of total particulate matter emissions.

TABLE 5-19. SUMMARY OF INFORMATION ON WET SCRUBBERS

Compound or Metal	Accompanying Control Device	Scrubber Type	Control Efficiency[a](%)	Source of Emissions	Reference
Adipic Acid			98	SOCMI	7
Cadmium			99 (Cd),89(Cd)	Fossil fuel combustion	
			77 (Cd)	Fossil fuel combustion	
			98,98	Primary lead smelting	73, 75
		Venturi		Primary zinc smelting	
Chlorobenzene		Venturi		SOCMI	7
Chromium		Venturi	96.1(Cr)	Coal and oil combustion	73, 75
		Venturi	88.9(Cr),90(Cr)	Coal and oil combustion	
			97 (Cr),95(Cr)	Coal and oil combustion	
			90 (Cr)	Oil combustion	
Dimethyl terephthalate				SOCMI	8
Manganese		Venturi	60 (Mn), 80 (Mn)	Fossil fuel combustion	
			98 (Mn), 87 (Mn)		
			79 (Mn)		
			90+	Ferroalloy production	49, 73
			99+	Iron and steel foundries	
			98.	Steel production	
Nickel	Cyclone			Primary nickel smelting	73, 74
				Secondary metals recovery	
		Venturi	95(Ni)	Coal and oil combustion	
			90.8-98(Ni)	Coal and oil combustion	
			97(Ni), 95(Ni)	Coal and oil combustion	
			83 (Ni)	Coal and oil combustion	
	ESP		>97 (Ni)	Coal and oil combustion	
Toluene diisocyanate[b]		Venturi		SOCMI	8
Phthalic anhydride	Thermal incinerator[c]	_[d]	96.5[e]	SOCMI	97, 131, 145
	Maleic acid recovery[f]				
	Thermal incinerator[c]	Venturi[g]	96.5[e]		
		Venturi			
Zinc		Venturi		Primary zinc smelting	77

[a] In terms of total particulate emissions unless otherwise noted.

[b] In toluene diisocyanate production, a wet scrubber is used to control emissions from the catalyst filtration unit. The emissions contain toluene diamine.

[c] The scrubber purge liquor is incinerated.

[d] The wet scrubber is a co-current system that treats 120,000 scfm of condenser off-gas. The recirculation rate of the scrubbing liquid is 5000 gpm.

[e] Efficiency for destruction of organics.

[f] Part of the scrubber purge liquor is treated further for maleic acid recovery.

[g] The water scrubbers consist of a venturi contactor followed by a packed column mist eliminator.

In some applications, scrubbers are used in conjunction with other control devices such as ESP's and cyclones.

No actual cost data for wet scrubber systems have been identified in the data base. However, References, 21, 23, 50, and 73 contain generalized design and cost information for wet scrubbers.

5.2.4 Cyclones

5.2.4.1 Introduction--

Cyclones are gas cleaning devices that utilize the centrifugal force created by a spinning gas stream to separate particulate matter from the carrier gas.[50] Cyclone collection efficiency decreases with dust particle size, particle density, inlet gas velocity, cyclone body length, and number of gas revolutions. It decreases with gas viscosity, cyclone diameter, gas outlet duct diameter, and gas inlet area.

5.2.4.2 Summary--

Table 5-20 summarizes the information on cyclone applications identified in the data base. The references on which this information is based are indicated in the table. References 24, 49, and 50 were used as general references.

Compound-specific information is not available in the references indicated in the table except in one case where the reported control efficiency is based on nickel emissions.

Cyclones have been used in combination with other particulate control devices. As indicated in the table, a wet scrubber and an ESP have been used with cyclones in controlling particulate emissions from primary nickel smelting and cement production.

TABLE 5-20. SUMMARY OF INFORMATION ON CYCLONES

Compound	Accompanying Control Device	Control Efficiency[a] (%)	Source of Emissions	Reference
Cadmium		85	Primary Copper Smelting	77
Copper		85	Primary Copper Smelting	77
Nickel	Scrubber		Primary Nickel Smelting	74
		97[b]	Nickel Matte Refining	
			Secondary Metals Recovery	
		80	Cement Production	
	ESP	97.5	Cement Production	
Zinc			Primary Zinc Smelting	77

[a] In terms of total particulate matter.

[b] All of the particulate emissions are assumed to be nickel.

SECTION 6

BIBLIOGRAPHY

The bibliography contains two sections. The first section lists the annotated bibliographic citations for the references obtained in the literature search. The second section classifies the citations according to the following six subject groups as shown in Table 3-2: physical/chemical properties; manufacturing information; reaction/process/industry descriptions; emission sources/rates/factors; emission controls; and general. A brief description of the groups appears at the end of this section.

6.1 ANNOTATED BIBLIOGRAPHY

1. Post, B. K., R. C. Mead, and A. S. Pelland. Air Toxics Information Clearinghouse: Bibliography of EPA Reports. EPA Contract No. 68-02-3513, Work Assignment 41. U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1984. 76p.

ABSTRACT: This bibliography contains a selected list of EPA reports which have been identified as being useful to State and local agencies developing and operating air toxics control programs. These reports include the following types of documents: health assessments, exposure assessments, source assessments, technical monitoring documents, methodologies for source sampling and ambient monitoring, and New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP) background information documents. All reports are indexed by document type, pollutant name/class, and source. The compilation of citations was complete as of January 1984.

2. White, R. E. Organic Chemical Manufacturing. Volume 1: Program Report. EPA-450/3-80-023. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 92p.

ABSTRACT: The EPA is developing new source performance standards under Section 111 of the Clean Air Act and national emission standards for hazardous air pollutants under Section 112 for volatile organic compound emissions (VOC) from organic chemical manufacturing facilities. In support of this effort, data were gathered on chemical processing routes, VOC emissions, control techniques, control costs, and environmental impacts resulting from control. These data have been analyzed and assimilated into the ten volumes comprising this report (see References 2-11). This volume contains a brief history of the four-year project and includes emission ranking information for 140 manufactured organic chemicals.

3. Blackburn, J. W. and R. L. Standifer. Organic Chemical Manufacturing. Volume 2: Process Sources. EPA-450/3-80-024. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 249p.

ABSTRACT: This volume covers the following process emission sources within organic chemical plants: air oxidation reactions, reactions involving carrier gases, vacuum producing systems, sulfuric acid recovery operations, and process upsets. This volume contains a detailed discussion of the carrier gas generic standard approach and explains its use for projecting VOC emissions.

4. Erikson, D. J., J. J. Cudahy, V. Kalcevic, and R. L. Standifer. Organic Chemical Manufacturing. Volume 3: Storage, Fugitive, and Secondary Sources. EPA-450/3-80-025. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 344p.

ABSTRACT: This volume covers emissions from storage tanks, fugitive sources (pump seals, valve seals, etc.), and secondary sources (emissions arising from treatment or disposal of process wastes).

5. Blackburn, J. W., J. A. Key, H. S. Basdekis, and V. Kalcevic. Organic Chemical Manufacturing. Volume 4: Combustion Control Devices. EPA-450/3-80-026. U. S. Environmental Protection Agency, Research Triangle, NC, December 1980. 354p.

ABSTRACT: This volume covers the following devices that can be used to control VOC emissions: thermal incinerators, catalytic incinerators, and flares. Data, tables, and curves and presented to enable preliminary cost and energy impacts to be determined for a wide range of potential applications.

6. Basdekis, H. S., D. G. Erikson, C. S. Parmele, and R. L. Standifer. Organic Chemical Manufacturing. Volume 5: Adsorption, Condensation, and Absorption Devices. EPA-450/3-80-027. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 335p.

ABSTRACT: This volume covers the following devices that can be used to control VOC emissions: carbon adsorbers, condensers, and absorbers. Data, tables, and curves are presented to enable preliminary cost and energy impacts to be determined for a wide range of potential applications.

7. Burce, W. D., J. W. Blackburn, V. Kalcevic, S. W. Dylewski, and R. E. White. Organic Chemical Manufacturing. Volume 6: Selected Processes. EPA-450/3-80-028a. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 404p.

ABSTRACT: This volume presents in-depth studies of the following major organic chemical products: cyclohexane, cyclohexanol, chlorobenzene, maleic anhydride, ethylbenzene, styrene, caprolactam, and adipic acid. Each product report contains information on the plants producing a particular chemical product or products, typical production routes, associated VOC emissions, feasible emission controls, control costs (from a new-plant perspective), and other impacts from application of the controls. Information is included on emissions from process vents, storage tanks, fugitive sources, and secondary sources, with emphasis on process vents.

8. Hobbs, F. D., C. W. Stuewe, S. W. Dylewski, D. M. Pitts, and C. A. Peterson. Organic Chemical Manufacturing. Volume 7: Selected Processes. EPA-450/3-80-28b. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 398p.

ABSTRACT: This volume presents in-depth studies of the following major organic chemical products: nitrobenzene, aniline, cumene, toluene diisocyanate, terephthalic acid, dimethyl terephthalate, phenol/acetone, and linear alkybenzenes. Each product report contains information on the plants producing a particular chemical product or products, typical production routes, associated VOC emissions, feasible emission controls, control costs (from a new-plant perspective), and other impacts from application of the controls. Information is included on emissions from process vents, storage tanks, fugitive sources, and secondary sources, with emphasis on process vents.

9. Key, J. A., C. W. Stuewe, R. L. Standifer, F. D. Hobbs, and D. M. Pitts. Organic Chemical Manufacturing. Volume 8: Selected Processes. EPA-450/3-80-28c. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 363p.

ABSTRACT: This volume presents in-depth studies of the following major organic chemical products: ethylene dichloride, carbon tetrachloride, perchloroethylene, fluorocarbons, 1,1,1-trichloroethane, trichloroethylene, vinylidene chloride, methyl chloride, methylene chloride, chloroform, and carbon tetrachloride. Each product report contains information on the plants producing a particular chemical product or products, typical production routes, associated VOC emissions, feasible emission controls, control costs (from a new-plant perspective), and other impacts from application of the controls. Information is included on emissions from process vents, storage tanks, fugitive sources, and secondary sources, with emphasis on process vents.

10. Lovell, R. J., J. A. Key, R. L. Standifer, V. Kalcevic, and J. F. Lawson. Organic Chemical Manufacturing. Volume 9: Selected Processes. EPA-450/3-80-28d. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 545p.

ABSTRACT: This volume presents in-depth studies of the following major organic chemical products: formaldehyde, methanol, ethylene, ethylene oxide, venyl acetate, acetaldehyde, ethanolamine, ethylene glycol, and glycol ethers. Each product report contains information on the plants producing a particular chemical product or products, typical production routes, associated VOC emissions, feasible emission controls, control costs (from a new plant perspective), and other impacts from application of the controls. Information is included on emissions from process vents, storage tanks, fugitive sources, and secondary sources, with emphasis on process vents.

11. Peterson, C. A., J. A. Key, F. D. Hobbs, J. W. Blackburn, and H. S. Basdekis. Organic Chemical Manufacturing. Volume 10: Selected Processes. EPA-450/3-80-28e. U. S. Environmental Protection Agency, Research Triangle Park, NC, 1980. 578p.

ABSTRACT: This volume presents in-depth studies of the following major organic chemical products: propylene oxide, acrylonitrile, glycerin and its intermediates (allyl chloride, epichlorohydrin, acrolein, and allyl alcohol), acrylic acid and esters, methyl methacrylate, chloroprene, butadiene, acetic anhydride, acetic acid, formic acid, ethyl acetate, and methyl ethyl ketone. Also included is a report on waste sulfuric acid treatment for acid recovery. Each product report contains information on the plants producing a particular chemical product or products, typical production routes, associated VOC emissions, feasible emission controls, control costs (from a new-plant perspective), and other impacts from application of the controls. Information is included on emissions from process vents, storage tanks, fugitive sources, and secondary sources, with emphasis on process vents.

12. Hossain, S. M., P. F. Cilicone, A. B. Cherry, and W. J. Wasylenko, Jr. Applicability of Coke Plant Control Technologies to Coal Conversion. EPA-600/7-79-184. U. S. Environmental Protection Agency, Research Triangle Park, NC August 1979. 212p.

ABSTRACT: The report gives results of comparisons of process and waste stream characteristics from the byproduct coke oven process with selected gasification and liquefaction processes. It includes recommendations regarding control technologies for air, water, and solid wastes. Coke oven control technology was reviewed extensively. State and Federal regulations for the disposal and treatment of coke oven wastes are presented, along with a brief assessment of health effects attributed to coke oven emissions. Study results indicate that a number of coke oven control technologies are applicable to coal conversion systems, especially those dealing with desulfurization, fugitive emissions, byproduct recovery/upgrading, and wastewater treatment. Byproduct upgrading and fugitive emission control technologies may be readily transferable to analogous coal conversion applications. Desulfurization and wastewater treatment technologies, however, cannot be transferred readily to applications where significant differences exist in the composition, temperature, and pressure of the two categories of process/waste streams. In these cases, laboratory or pilot plant scale tests will be required with actual coal conversion wastes to determine the design bases and the treatability variations between coal conversion and comparable coke oven streams.

13. Coke Oven Emissions from By-Product Coke Oven Charging, Door Leaks, and Topside Leaks on Wet-Charged Batteries - Background Information for Proposed Standards. Draft. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1981.

ABSTRACT: Coke oven emissions consist of a yellow-brown gas which contains over 10,000 compounds as gases, condensible vapors, and particulates. The components of concern to public health include benzene and a class of compounds termed polycyclic organic matter (POM). This report presents a profile of the by-product coke industry and suggests three regulatory alternatives for each of the following emissions sources: wet-coal charging, door leaks, and topside leaks. For each alternative, environmental and economic impacts are considered. Emission control techniques for each of the sources are described. The appendices contain detailed information on the evolution of the proposed standards, an index to environmental impact considerations, emission source test data, a discussion of emission measurements and continuous monitoring, and a summary of the background and methodology used to determine the health-risk assessment.

14. Benzene Emissions from Coke By-Product Recovery Plants - Background Information for Proposed Standards. Preliminary Draft. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1981.

ABSTRACT: This report presents a profile of the coke oven gas by-product industry and suggests three regulatory alternative for controlling benzene emissions. The environmental and economic impacts of each of the alternatives are summarized. Emission control technologies and process modifications are described. Eleven emission sources are characterized. Major emphasis is given to demonstrated emission controls for by-product recovery sources, such as gas blanketing.

15. Metzger, D. J. Development of the Two-Step-Quench (TSQ) System. In: A Specialty Conference on Air Pollution Control in the Iron and Steel Industry, Chicago, IL, April 21-23, 1981. Air Pollution Control Association, Pittsburgh, PA, 1981. pp. 108-113. (2 figures)

ABSTRACT: This paper discusses the factors leading to the development of a new method and new approach to control of coke pushing emissions. Early developmental experiments are set forth and the new method for controlling coke pushing and coke quenching emissions is described. Results of emission tests and the conclusions drawn from the tests are discussed. Finally, the rationale for virtually eliminating pushing emissions and reduction of quench station emissions is explained.

16. Jasinski, M. R. Status of Coke Pushing Emissions Control and Available Emissions Data. In: A Specialty Conference on Air Pollution Control in the Iron and Steel Industry, Chicago, IL, April 21-23, 1981. Air Pollution Control Association, Pittsburgh, PA, 1981. pp. 114-120. (4 references, 5 tables, 4 figures)

ABSTRACT: This paper lists existing and on-order push control devices by individual batteries. Approximately 50 percent of all active coke batteries in the United States were fitted with a pushing emissions control system as of June 1980. Data are presented showing the number of controlled batteries by year from 1970 and 1982 and a breakdown of each type of push control system currently installed and in-order. Available emission data describing visible emissions escaping capture and outlet mass concentration from gas cleaning devices are also presented. (4 references)

17. Liepins, R., F. Mixon, C. Hudak, and T. B. Parsons. Industrial Process Profiles for Environmental Use. Chapter 6: The Industrial Organic Chemicals Industry. EPA-600/2-77-023f. U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1977. 1014p.

ABSTRACT: The catalog of Industrial Process Profiles for Environmental Use was developed as an aid in defining the environmental impacts of industrial activity in the United States. Entries for each industry are in consistent format and form separate chapters of the study. Industrial organic chemicals are the product of at least one chemical reaction in this industry and will undergo at least one additional treatment step in a downstream processing industry. These compounds are intermediate materials in the manufacture of such products as plastics, synthetic fibers, pharamaceuticals and surfactants among others. The industry is discussed in terms of ten feedstock groups: benzene, butylenes, sources of cresylic acids, ethylene, methane, naphthalene, paraffins, propylene, toluene, and xylenes. Ten chemical trees, ten process flow sheets, and 365 process descriptions have been prepared to characterize the industry. Within each process description available data have been presented on function, input materials, operating parameters, utilities, waste streams, EPA Source Classification Code and references. Data related to the subject matter, including company, product and raw material data, are included as appendices.

18. Parsons, T. B., C. M. Thompson, and G. E. Wilkins. Industrial Process Profiles for Environmental Use. Chapter 5: Basic Petrochemicals Industry. EPA-600/2-77-023e. U. S. Environmental Protection Agency, Research Triangle Park, NC, January 1977. 154p.

ABSTRACT: The catalog was developed to aid in defining the environmental impacts of U. S. industrial activity. Entries for each industry are in consistent format and form separate chapters of the catalog. The basic petrochemicals industry includes companies that treat hydrocarbon streams from the petroleum refining industry, as well as natural gas liquids from the oil and gas production industry. From these raw materials, feedstocks are produced for the organic chemicals industry. The products are pure or mixed chemicals for use as solvents or chemical intermediates. This industry is described by six operations composed of related processes. Four chemical trees, six process flow sheets, and 28 process descriptions characterize the industry. For each process description, available data is presented on input materials, operating parameters, utility requirements, and waste streams. Related information, provided as appendices, includes company, raw material, and product data.

19. Beverage Can Surface Coating Industry - Background for Proposed Standards. EPA-450/3-80-036a. U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1980. 230p.

ABSTRACT: Standards of Performance for the control of emissions from the beverage can surface coating industry are being proposed under the authority of Section 111 of the Clean Air Act. These standards would apply to all beverage can surface coating lines for which construction or modification began on or after the date of proposal of the regulations. This document contains background information and environmental and economic assessments of the regulatory alternatives considered in developing the proposed standards.

20. VOC Emissions from Volatile Organic Liquid Storage Tanks - Background Information for Proposed Standards. EPA-450/3-81-003a. U. S. Environmental Protection Agency, Research Triangle Park, NC, 1981, 199p.

ABSTRACT: Standards of Performance for the control of VOC emissions from the volatile organic liquid (VOL) storage tanks are being proposed under the authority of Section 111 of the Clean Air Act. These standards would apply to all new and existing storage tanks having the capacity of 75 cubic meters or larger, which are to be used for the storage of VOL. This document contains background information and environmental and economic assessments of the regulatory alternatives considered in developing the proposed standards.

21. Hardison, L. C. Air Pollution Control Technology and Costs in Seven Selected Areas. EPA-450/3-73-010. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1983. 724p.

ABSTRACT: The following seven industrial areas are discussed: (1) Phosphate industry; (2) Feed and Grain Industry; (3) Paint and Varnish Industry; (4) Graphic Arts Industry; (5) Soap and Detergent Industry; (6) Lime Kilns; and (7) Gray Iron Foundries. The technical material consists of a narrative description of each of the process areas, specifications for air pollution abatement equipment for each, and a summary of capital and operating costs for equipment.

22. Control Techniques for Volatile Organic Emissions from Stationary Sources. EPA-450/2-78-022. U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1978. 578p.

ABSTRACT: This document is a revised and updated version of a March 1970 EPA publication entitled Control Techniques for Hydrocarbon and Organic Solvent Emissions from Stationary Sources (AP-68). The document is intended primarily as a general reference for State and local air pollution control engineers. It provides: (1) basic information on sources of photochemical oxidant precursors and control of these sources; (2) estimates of control costs; (3) estimates of control technique energy requirements; and (4) estimates of emission reductions achievable through control application.

23. Neveril, R. B. Capital and Operating Costs of Selected Air Pollution Control Systems. EPA-450/5-80-002. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1978. 285p.

ABSTRACT: This manual provides capital and operating costs for air pollution control systems. Capital costs are provided for component equipments, such as ductwork, dampers, heat exchangers, mechanical collectors, fans, motors, stacks, cooling towers, pumps, and dust removal equipment. Eight types of control devices are included: (1) high voltage electrostatic precipitators; (2) venturi scrubbers; (3) fabric filters; (4) thermal and catalytic incinerators; (5) adsorbers; (6) absorbers; (7) refrigeration; and (8) flares. Operating and maintenance costs are provided for complete systems. A discussion of the control devices and factors affecting costs is included, along with design parameters for 52 industries. In preparing this manual, the main objective was to "break-out" the individual component costs so that realistic system cost estimates can be determined for the design peculiarities of any specific application.

24. Modern Pollution Control Technology. Volume I: Air Pollution Control. M. Fogiel, (ed). Research and Education Association, New York, NY, 1978. 1086p.

ABSTRACT: This volume reviews the state-of-the-art of air pollution control technology. The technical and economic feasibility of processes, equipment, and plants are analyzed. A large amount of information for this volume was contributed by the U. S. Environmental Protection Agency and the Los Angeles Air Pollution Control District. Twenty pages of references are included.

25. Control Techniques for Hydrocarbon and Organic Solvent Emissions from Stationary Sources. AP-68. U. S. Department of Health, Education, and Welfare, Washington, DC, March 1970. 114p.

ABSTRACT: This report summarizes information on stationary sources of hydrocarbon and organic solvent emissions, methods of control, and the costs and cost effectiveness of controls. Methods used to control hydrocarbon and organic solvent emissions are: (1) operational or process charges; (2) substitution of materials; and (3) installation of control equipment. Four techniques used in control devices are discussed: incineration, adsorption, absorption, and condensation. Control systems for the following industrial processes are reviewed: petroleum refineries; gasoline distribution systems; chemical plants; paint, lacquer and varnish manufacture; rubber and plastic products manufacture; surface coating applications; degreasing operations; dry cleaning; stationary fuel combustion; metallurgical coke plants; sewage treatment; and waste incineration and other burning. The economic considerations which are discussed include: (1) definition of alternatives; (2) identification of costs; (3) cost curves by equipment types; (4) value of recovered materials; (5) selection of control systems, and (6) assessment of economic impact.

26. Engineering Control Technology Assessment for the Plastics and Resins Industry. DHEW(NIOSH) Publication No. 78-159. U. S. Department of Health, Education, and Welfare, Cincinnati, OH, March 1978. 234p.

ABSTRACT: A control technology assessment for the plastics and resins industry was made by conducting in-depth surveys of 15 polymerization and compounding processes. The processes selected provided a representative coverage of the industry relative to the number of exposed workers, different control techniques, and commonality of operations. Each case study addressed the following topics: major toxic chemicals and harmful physical stresses; engineering controls and work practices; workplace monitoring systems and air sampling programs; personal protection equipment; exposure data and conclusions; and planned or ongoing improvements. The results of this study are useable as a reference resource by both industry and government personnel. A number of problem areas in systems analysis, mechanical engineering design, research and testing, and ventilation control are identified as likely candidates for further research and development. (60 references)

27. Formica, P. N. Control and Uncontrolled Emission Rates and Applicable Limitations for Eighty Processes. EPA-450/3-77-016. U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1976. 410p.

ABSTRACT: The report contains quantitative information for 80 source categories which are considered common to many areas of the U. S. and would potentially benefit most from application of control devices. The 80 source categories are assessed according to (1) typical plant size and associated particulate matter and/or hydrocarbon emissions; (2) applicable control equipment efficiencies; and (3) potential for compliance with certain emission limitations. The document presents data typical of current emissions and control techniques. The document also lists selected emission limitations.

28. Taback, H. D., T. W. Sonnichsen, N. Brunetz, and J. L. Stredler. Control of Hydrocarbon Emissions from Stationary Sources in the California South Coast Air Basin. California Air Resources Board, Sacramento, CA, June 1978. 459p.

ABSTRACT: This study discusses an inventory of gaseous organic emissions from stationary sources, which was conducted in the California South Coast Air Basin. It includes the development of 140 unique emission profiles to describe hydrocarbon emissions for 740 SCC/SIC categories. The various profiles identified from one to 30 different species. The inventory accounted for all known stationary source organic emissions including major and minor point sources, and area sources (oil production fields, architectural coatings, domestic solvent usage, etc.). The inventory was prepared in the EPA's Emission Inventory Subsystem (EIS) format. All sources were located by Universal Transverse Mercator (UTM) coordinates. Also, control technique descriptions, application considerations and cost-effectiveness data were compiled. Finally, a prediction of emission trends based on expected growth and control strategies was made.

29. Khan, Z. S. and T. W. Hughes. Source Assessment: Chlorinated Hydrocarbon Manufacture. EPA-600/2-79-019g. U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1979. 188p.

ABSTRACT: The report describes a study of air pollutants released during the manufacture of chlorinated hydrocarbons by: (1) direct chlorination (a hydrocarbon is reacted with chlorine); (2) hydrochlorination (hydrogen chloride is reacted with a hydrocarbon); (3) oxyhydrochlorination (hydrogen chloride is reacted with a hydrocarbon in the presence of oxygen or air); or (4) chlorohydrination (the reaction between a hydrocarbon and hydrochloroous acid is followed by a reaction of the products with lime slurry to obtain the final report). A representative plant was defined for each manufacturing process type, and environmental effects were determined on the basis of plant capacity. The potential environmental effect was evaluated using source severity, S, defined as the ratio of the maximum ground level concentration of an emission to the ambient air quality standard for criteria pollutants. Source severities for the four processes listed above are 1.69, 1.94, 31.3, and 2.75 respectively.

30. Eimutis, E. C., R. P. Quill, and G. M. Rinaldi. Source Assessment: Noncriteria Pollutant Emissions (1978 Update). EPA-600/2-78-004t. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1978. 148p.

ABSTRACT: This report provides a listing of stationary source types that emit each of 389 noncriteria pollutants. Quantities of such emissions are also indicated. A source type is defined as a group of emission sources which have the same process and emission characteristics. The listing was prepared using a computerized data base established for emissions of air pollutants from approximately 800 stationary source types in the combustion, organic materials, inorganic materials, and open source categories. Emissions included in the data base consist of criteria pollutants (i.e., particulates, sulfur dioxide, nitrogen oxides, hydrocarbons, and carbon monoxide) and noncriteria pollutants (such as trace metals and polycyclic organic matter). The data base is updated continuously to incorporate related new findings and covers a large number of source types; however, it is not an exhaustive list of all stationary emission points in the United States.

31. Horn, D. A., D. R. Tierney, and T. W. Hughes. Source Assessment: Polychloroprene. State of the Art. EPA-600/2-77-107o. U. S. Environmental Protection Agency, Research Triangle Park, NC., 1977, 97p.

ABSTRACT: This document reviews the state of the art of air emissions from polychloroprene manufacture. The composition, quality, and rate of emissions and their environmental effects are described. Polychloroprene is produced by the emulsion polymerization of 2-chloro-1,3-butadiene (chloroprene). Emissions include hydrocarbons, particulates, hydrogen chloride, and nitrogen oxides. To assess the severity of emissions from this industry, a representative plant was defined based on mean values for plant parameters. Source severity was defined as the ratio of the time-averaged maximum ground level concentration of an emission to the primary AAQS for criteria pollutants or to a reduced TLV for noncriteria pollutants. For a representative plant, source severities for particulates, hydrocarbons, nitrogen oxides, chloroprene, toluene, hydrogen chloride, and talc are 0.03, 23, 0.1, 4.3, 0.4, 0.9, and 3.4, respectively. Hydrocarbon emissions are controlled through a combination of process modifications. Particulates are controlled by exhaust systems in conjunction with wet scrubbers or fabric filters. Hydrogen chloride emissions are reduced by falling film absorbers and packed scrubbers.

32. Health Assessment Document for Toluene. EPA-600/8-82-008f. U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1983. 427p.

ABSTRACT: Toluene is the most prevalent hydrocarbon in the atmosphere. Levels generally range from 0.14-57 ppb. Levels in water generally are below 10 ppb. Gasoline usage and automobile exhaust represent the largest atmospheric source. Over 3 million metric tons of toluene are produced annually in the United States. Available evidence associated with effects upon humans and experimental animals indicates that the health effect of primary concern is dysfunction of the central nervous system (CNS). However, observed effects are associated with exposure levels greatly in excess of those levels in the environment. Dysfunction of the CNS may occur during short-term ($\leq$8 hours) exposure to 100-300 ppm. Toluene has not demonstrated any overt signs of kidney or liver damage upon animal experimentation. It was noncarcinogenic in rats exposed to 300 ppm for 24 months. However, the full extent of toluene's carcinogenic potential is currently being evaluated, at higher exposure levels, in a lifetime bioassay of rodents in the National Toxicology Program. Toluene is classified as provisionally nonmutagenic, and its teratogenic potential has not been fully explored. The results of the available evidence indicate that exposure to environmental levels of toluene is unlikely to constitute a significant hazard to the general population.

33. Anderson, L. D., S. Bayard, I. W. F. Davidson, J. R. Fowle, III, H. J. Gibb, M. Greenberg, and J. C. Parker. Health Assessment Document for Trichloroethylene. External Review Draft. EPA-600/8-82-006b. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1983. 397p.

ABSTRACT: Trichloroethylene (TCI) is a solvent widely used in the industrial degreasing of metals. It has been detected in the ambient air of a variety of urban and non-urban areas of the United States and also in natural and municipal waters. The weight of available evidence obtained from both animal and human data suggest that long-term exposure to environmental levels of TCI poses no serious health concern to the general population. No teratogenic potential has been demonstrated for TCI in studies conducted to date with experimental animals. With respect to the mutagenic potential of TCI, the data on pure TCI do not allow a conclusion to be drawn. If TCI is mutagenic, the available data suggest it would be a very weak, indirect mutagen. Based on available animal cancer data, the classification of TCI under the criteria of the International Agency for Research on Cancer (IARC) could either be "sufficent" or "limited". Because there are no adequate epidemiologic data, the overall ranking of TCI would place it in a category in which it would be a probably human carcinogen or one that cannot be classified as to its carcinogenicity.

34. Cleland, J. G., G. L. Kingsbury, R. C. Sims, and J. B. White. Multimedia Environmental Goals for Environmental Assessment, Volumes 1 and 2. EPA-600/7-77-136a and EPA-600/7-77-136b. U. S. Environmental Protection Agency, Research Triangle Park, NC, November 1977. 366p, 451p.

ABSTRACT: The report gives results of a study of the derivation of Multimedia Environmental Goals (MEG's). MEG's are levels of significant contaminants or degradents (in ambient air, water, or land, or in emissions or effluents conveyed to the ambient media) that are judged to be either appropriate for preventing certain negative effects in the surrounding populations or ecosystems or representative of the control limits achievable through technology. In the context of deriving MEG's, Volume 1 offers perspective on the broad range of contaminants whose control is vital to both industry and the public; further develops and defines indicators designating contaminants which must be given priority consideration for immediate control and for subsequent research; brings existing and emerging data together for use in environmental assessment; and explores some basic methodologies which provide the present MEG's, and which also suggest directions for refined methodologies. MEG's are projected for more than 650 pollutants. Of these, 216 substances receive full attention in Volume 2. MEG charts along with the Background Information Summaries for these substances are presented in this volume which includes 162 organic and 54 inorganic substances.

35. Wehrum, B., S. Ahmed and B. Davis. Air Toxics Emission Patterns and Trends. EPA Contract No. 68-02-3513. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1984, 96p.

ABSTRACT: This study reviews the available literature (published and unpublished documents which can be readily obtained) summarizing data on the emission sources of a list of 87 toxic air pollutants. The report provides a qualitative summary of the emission source characteristics of the 87 chemicals. Both traditional and nontraditional sources of toxic air pollutants are examined. The traditional sources include industrial process emissions, mobile source emissions, and emissions from combustion and solvent use. Nontraditional sources include emissions from the treatment, storage, and disposal of liquid and solid wastes. The purpose of the study is to assist EPA to determine which compounds should be further evaluated as candidates for controls under Section 112 of the Clean Air Act, the National Emissions Standards for Hazardous Air Pollutants (NESHAPS).

36. Air Quality Data for Noncriteria Pollutants - 1957 through 1970. EPA-450/2-77-020. U. S. Environmental Protection Agency, Research Triangle Park, NC, November 1977. 376p.

ABSTRACT: This report presents a comprehensive inventory of data produced by analysis of hi-vol filters for trace metals and inorganic ions for the years 1957-1970. This inventory is based on data acquired through extensive monitoring activities conducted by Federal, State, and local pollution control agencies and submitted to the U. S. Environmental Protection Agency's National Aerometric Data Bank.

37. Baines, T. M. Nitrosamines and Other Hazardous Emissions from Engine Crankcases. EPA/AA/CTAB/PA/85-15. U. S. Environmental Protection Agency, Ann Arbor, MI, June 1981. 15p.

ABSTRACT: The emissions from heavy duty diesel crankcases contain a number of hazardous compounds. Research has discovered some of them and it may be possible that there are some that have not yet been quantified. Nitro-

samines (a potent carcinogen in animals and probably also in humans) are emitted from engines using fresh oil. These emissions seem to be a function of the type of oil used and some engine parameters such as crankcase flow rate of NO_x compounds. Used lubricating oil has been shown to contain carcinogenic compounds such as benzo-a-pyrene. It has also been shown to be mutagenic. Therefore, it can be concluded that the particulate portion of the crankcase effluent stream may start out after an oil change at a level containing few carcinogenic compounds but the level of these compounds increases with time. In conclusion, crankcases emit a variety of hazardous chemicals and evaluation of the costs and benefits of the control of these emissions should be seriously considered.

38. PCB Disposal by Thermal Destruction. EPA-906/9-82-003. U. S. Environmental Protection Agency, Dallas, TX, June 1981. 610p.

ABSTRACT: A report on the sampling, analysis, and consideration of risks and benefits associated with the incineration of polychlorinated biphenyls (PCBs) at two commercial facilities in Deer Park, Texas and El Dorado, Arkansas. Included are a summary, PCB incineration test reports, polychlorinated dibenzo-p-dioxin (PCDD) and polychlorinated dibenzofuran report (PCDF) emission sampling reports, a PCDD and PCDF analytical chemistry report, air dispersion modeling results, an analysis of risks and benefits, and letters and conditions of approval.

39. Fuller, B., J. Hushon, M. Kornreich, R. Ouellette, and L. Thomas. Preliminary Scoring of Selected Organic Air Pollutants. EPA-450-/3-77-008a. U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1976. 114p.

ABSTRACT: This report presents a scheme for evaluating the relative hazard to human resulting from air emissions of synthetic organic chemicals. Data on production, fraction lost during production, volatility, and toxicity have been compiled for 637 organic chemicals. Numerical scores were then assigned based on these data. Four appendices were published with this report. The appendices are dossiers containing chemistry, production, and toxicity data for the 637 synthetic organic chemicals. (See References 40 through 43.)

40. Dorigan, J., B. Fuller, and R. Duffy. Preliminary Scoring of Selected Organic Air Pollutants. Appendix I: Chemistry, Production and Toxicity of Chemicals A through C. EPA-450/3-77-008b. U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1976. 330p.

ABSTRACT: This is the first of the series of four appendices to the report Preliminary Scoring of Organic Air Pollutants. The entire appendix contains a compilation of available data on chemical structure and properties, environmental persistence, production, and toxicity for 637 synthetic organic chemicals. This volume covers the chemicals acenaphthene through cyprex.

41. Dorigan, J., B. Fuller, and R. Duffy. Preliminary Scoring of Selected Organic Air Pollutants. Appendix II: Chemistry, Production, and Toxicity of Chemicals D through E. EPA-450/3-77-008c. U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1976. 336p.

ABSTRACT: This is the second of the series of four appendices to the report Preliminary Scoring of Organic Air Pollutants. The entire appendix contains a compilation of available data on chemical structure and properties, environmental persistence, production, and toxicity for 637 synthetic organic chemicals. This volume covers the chemicals dacthal through ethyl silicate.

42. Dorigan, J., B. Fuller, and R. Duffy. Preliminary Scoring of Selected Organic Air Pollutants. Appendix III. Chemistry, Production, and Toxicity of Chemicals F through N. EPA-450/3-77-008d. U. S. Environmental Protection Agency, Research Triangle, NC, October 1976. 312p.

ABSTRACT: This is the third of the series of four appendices to the report Preliminary Scoring of Organic Air Pollutants. The entire appendix contains a compilation of available data on chemical structure and properties, environmental persistence, production, and toxicity for 637 synthetic organic chemicals. This third volume covers the chemicals ferbam through nonyl phenol.

43. Dorigan, J., B. Fuller, and R. Duffy. Preliminary Scoring of Selected Organic Air Pollutants. Appendix IV. Chemistry, Production, and Toxicity of Chemicals F through N. EPA-450/3-77-008e. U. S. Environmental Protection Agency, Research Triangle, NC, October 1976. 333p.

ABSTRACT: This is the fourth of the series of four appendices to the report Preliminary Scoring of Organic Air Pollutants. The entire appendix contains a compilation of available data on chemical structure and properties, environmental persistence, production, and toxicity for 637 synthetic organic chemicals. This fourth volume covers the chemicals octyl alcohol through zinc stearate. Also, it contains a chemical name index.

44. Directory of Chemical Producers United States of America 1984. S.R.I International, Menlo Park, CA, 1984. 1088p.

ABSTRACT: The information in the directory is organized into three major sections: Companies, Products, Regions. The Companies section is an alphabetical list of 1500 companies and their products, listed by site of manufacture. The Products section is an alphabetical listing of chemicals and end-use grouping of chemicals. One important feature of the Products section is the inclusion of plant production capacities for over 240 major commodity chemicals, polymers, and fibers. The Regions section is an alphabetical listing of all the states and is generated from the Companies section.

45. Chemical Hazard Information Files (CHIPs). EPA-560/11-80-011. U. S. Environmental Protection Agency, Washington, DC, April 1980. 296p.

ABSTRACT: This collection of 40 Chemical Hazard Information Profiles (CHIPs) reports was prepared by the Office of Pesticides and Toxic Substances (OPTS) between August 1, 1976, and November 20, 1979. Chemicals are chosen for CHIP preparation on the basis of information indicating potential for adverse health or environmental effects of significant exposure. The CHIP itself is a brief summary of readily available information concerning health and environmental effects and exposure potential of a chemical. Information gathering for a CHIP is generally limited to a search of secondary literature sources and is not intended to be exhaustive; however, in depth searches on specific topics may be done on a case-by-case basis. In general, no attempt is made to evaluate or validate information at this stage of assessment. Preparation of a CHIP is part of the first stage in the OPTS Chemical Risk Assessment Process. The purpose of the CHIP is to enable OPTS to make a tentative decision on an appropriate course of action for the subject chemical and to identify and characterize problems that may require more thorough investigation and evaluation.

46. Polychlorinated Biphenyls in the Environment. September 1980 - February 1983 (Citations from the NTIS Data Base). PB83-804716. National Technical Information Service, Springfield, VA, March 1983. 154p.

ABSTRACT: The environmental aspects of polychlorinated biphenyls (PCBs) are cited in this bibliography. Most of the studies are concerned with the toxicity, ecology, and abundance of PCBs in water and air. (This updated bibliography contains 145 citations, 75 of which are new entries to the previous edition.)

47. Sableski, J., B. Hogarth, J. Pearson, and P. Mansfiel. Air Programs Reports and Guidelines Index. EPA-450/2-82-016. U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1982. 56p.

ABSTRACT: The Index represents a compilation of current technical and guideline documents prepared by the Office of Air Quality Planning and Standards (OAQPS) over the past several years. It is intended for the use by officials of State and local agencies as a companion document to the Air Programs Policty and Guidance Notebook. It will provide information to State and local air pollution control agencies in conducting air quality programs.

48. Merrick, E. T. Chemical Activities Status Report. Third Edition. Volumes 1 and 2. EPA-560/TIIS-82-002a and EPA-560/TIIS-82-002b. U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1982. 404p, 412p.

ABSTRACT: Volume I provides names and synonyms for chemicals included in the data base, both alphabetically and by registry number. Volume II gives brief descriptions of chemical-specific regulations, guidelines, and studies of the EPA. Together, the reports permit users to identify chemical of interest to the EPA, and describe the EPA activities related to those chemicals.

49. Nelson, T. P., A. E. Schmidt, S. A. Smith. Study of Sources of Chromium, Nickel, and Manganese Air Emissions. EPA Contract No. 68-02-3818, Task 34. Radian Corporation, Austin TX, February 24, 1984. 326p.

ABSTRACT: The report provides preliminary information on sources of air emissions of chromium, nickel, and manganese. Releases of these metals to water and soil are included when information is available. Fifteen source categories are examined. The estimated uncontrolled, current controlled, and estimated best control (EBC) controlled emission rates for each source category are listed. These emissions estimates include both process and fugitive emissions. Control costs are estimated for each category.

50. Control Techniques for Particulate Air Pollutants. AP-51. U. S. Department of Health Education, and Welfare. Washington, DC, January 1969. 215p.

ABSTRACT: The following sources of particulate air pollution are identified and discussed: internal combustion engines, stationary combustion sources, industrial sources, construction and demolition, and solid waste disposal. Gas cleaning devices, such as settling chambers, dry centrifugal collectors, wet collectors and mist eliminators, high-voltage and low-voltage electrostatic precipitators, fabric filters, and afterburners, are described. Emission factors for particulates are listed and the costs and cost effectiveness of control are considered. The report contains an extensive bibliography arranged by specific source categories.

51. Polcyn, A. J. PCB Waste Destruction Study: High Efficiency Boiler. In: Proceedings of a Specialty Conference on the Measurement and Monitoring of Noncriteria (Toxic) Contaminants in Air, Chicago, IL, March 22-24, 1983. SP-50. Air Pollution Control Association, Pittsburgh, PA, 1983. pp. 361-373.

ABSTRACT: This paper describes a test burn program conducted by Union Electric of St. Louis, Missouri on its Labadie Unit #4 boiler. The purpose was to demonstrate a PCB destruction efficiency equivalent to an Annex I incinerator while burning pulverized coal on the primary fuel source and injecting a 5 percent PCB/mineral oil blend. Three conclusions are drawn from the program: (1) PCB destruction efficiency of the Unit #4 boiler is greater than that of an Annex I incinerator; (2) the Unit #4 boiler is a high efficiency boiler capable of the safe and complete destruction of waste oils containing a 5 percent PCB/mineral oil blend; and (3) the use of a modified EPA Method 5 high volume source sampling train provides for the reasonably rapid collection of a large sample volume essential for demonstrating high destruction efficiencies in the combustion of PCBs.

52. Hoff, M. C. Toluene. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 23. John Wiley & Sons, Inc., New York, NY, 1982. pp. 246-273.

ABSTRACT: This article discusses the chemical and physical properties of toluene, its manufacture, and its major uses. U. S. production and sales and plant capacities are given. The article describes specifications, test methods and analysis, and lists procedures for safety and handling. In addition, the manufacture of the following derivatives is described: benzene, toluene diisocyanate, benzoic acid, benzyl chloride, vinyltoluene, toluenesulfonic acid, benzaldehyde, toluenesulfonyl chloride. Potential uses of toluene are discussed. (75 references, 21 tables, 7 figures.)

53. Johnson, P. R. Chloroprene. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 5. John Wiley & Sons, Inc., New York, NY, 1982. pp. 773-785.

ABSTRACT: This article discusses the chemical and physical properties of chloroprene, its manufacture, and its major uses. Because most chloroprene is currently produced from butadiene, only this manufacturing route is described. Other topics include storage, handling and shipment; waste disposal; economic and energy factors; specifications, standards, and quality control; and health and safety factors (toxicology). (101 references, 3 tables, 1 figure.)

54. Gelfand, S. Chlorocarbons, Chlorohydrocarbons (Benzyl): Benzyl Chloride, Benzal Chloride, Benzotrichloride. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 5. John Wiley & Sons, Inc., New York, NY, 1982. pp. 828-838.

ABSTRACT: This article describes the chemical and physical properties of benzyl chloride [100-44-7], benzal chloride [98-87-3], and benzotrichloride [98-07-7], their methods of manufacture, and their major uses. In addition, the article discusses handling and shipment; economic aspects, such as total production, sales, and unit value; identification and analysis; health and safety factors (toxicology); and derivatives. (73 references, 3 tables)

55. Hess, L. G., A. N. Kurtz, and D. B. Stanton. Acrolein and Derivatives. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 1. John Wiley & Sons, Inc., New York, NY, 1982. pp. 277-297.

ABSTRACT: This article discusses the chemical and physical properties of acrolein and methacrolein, their manufacture, and their major uses. The reactions and derivatives of acrolein are described. Other information includes statistics on production and capacity, specifications and analytical methods, and procedures for safe storage and handling. (183 references, 7 tables, 1 figure.)

56. Archer, S. R., W. R. McCurley, and G. D. Rawlings. Source Assessment: Pesticide Manufacturing Air Emissions -- Overview and Prioritization. EPA-600-2/-78-004d. U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1978. 153p.

ABSTRACT: This report is an overview of the pesticide manufacturing industry and prioritizes 80 major pesticides based on their potential environmental burden from an air pollution standpoint. Production of synthetic organic pesticides was about 640,000 metric tons in 1974. Thirty-seven major synthetic organic pesticides, those with annual production of 4,540 or more tons, accounted for 74 percent of the market. Elemental chlorine is common to most pesticides, but other raw materials include hydrogen cyanide, carbon disulfide, phosgene, phosphorus pentasulfide, hexachloro-cyclopentadiene, various amines, and concentrated acids and caustics. Air pollution aspects of the pesticide manufacturing industry are essentially without quantitative data. For some plants, the pollution caused by loss of active ingredients is less significant than that caused by unreacted by-products. Evaporation from holding pond and evaporation lagoons may also be an emission source, although few quantitative data are available. Emissions emanate from various pieces of equipment and enter the atmosphere as both the active ingredient and as raw materials, intermediates, and by-products. Air emission control devices include baghouses, cyclone separators, electrostatic precipitators, incinerators, and gas scrubbers. Synthetic organic pesticide production in 1985 will be about 806,000 metric tons.

57. Meinhold, T. F. Fume Incinerators for Air Pollution Control. Plant Engineering (Barrington, IL), 34(23): 108-115, 1980.

ABSTRACT: Fume incineration is one of the most effective and reliable methods for destroying organic emissions from industrial plants. This article discusses two basic combustion systems - thermal and catalytic oxidation - along with heat recovery options, costs, installation, operation, safety, and maintenance. Case studies are included. (3 tables, 11 figures.)

58. Kenson, R. E., and R. O. Hoffland. Control of Toxic Air Emissions in Chemical Manufacture. Chemical Engineering Progress, 76(2): 80-83, 1980.

ABSTRACT: Controlling toxic air emissions in chemical manufacture requires the use of engineered systems rather than off-the-shelf units. A cost effective system for VCM emissions in a polyvinyl chloride plant must take into account the variable emissions flow rate. Considering all the factors, a carbon adsorption system in which large quantities of VCM can be recovered will pay for itself in about three years. In addition, pilot and full-scale tests showed that such a system could meet the EPA's 5 ppm emission limitations. Although thermal incineration is lower in capital cost, it has no such payback. (3 tables, 3 figures.)

59. Wilhelmi, A. R. and P. V. Knopp. Wet Air Oxidation: An Alternative to Incineration. Chemical Engineering Progress, 75(8): 46-52, 1979.

ABSTRACT: As landfills, ocean dumping, and deep well injection become more unacceptable as methods for hazardous waste disposal, alternative technologies must be sought. One technology, incineration, is quite often considered. Another technology, however, the Zimmermann Process of Wet Air Oxidation (WAO), is often most cost-effective. This article describes WAO and documents its performance in treating hazardous wastes. A cost comparison with incineration is also presented with a special emphasis on the total treatment costs and technical considerations for both technologies. Cost comparisons indicate that WAO is greater in capital costs but less expensive to operate. Total operating costs including amortization favor WAO when the fuel value of the waste organics is low (less than approximately 50 g/L Chemical Oxygen Demand. (6 references, 8 tables, 7 figures.)

60. Kenson, R. E. Carbon Adsorption of Hydrocarbon Emissions Using Vacuum Stripping. Pollution Engineering, 11(7): 38-40, 1979.

ABSTRACT: Carbon adsorption with steam stripping has successfully controlled a large variety of hydrocarbon emissions in numerous industrial processes. Optimum system design can achieve greater than 90 percent control of the emissions and can also pay back the system cost in one to five years through recovery of reusable chemical solvents or reagents. This article presents operating principles, application examples in both pharmaceuticals and PVC resin manufacture, and an economic evaluation of a vacuum stripped carbon adsorption method. (2 figures.)

61. Vincent, E. J. and W. M. Vatavuk. Control of Volatile Organic Emissions from Existing Stationary Sources. Volume 8: Graphic Arts: Rotagravure and Flexography. EPA-450/2-78-033. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1978. 52p.

ABSTRACT: This report provides guidance for development of regulations to limit emissions of volatile organic compounds from rotogravure and flexographic printing operations. This guidance includes recommended control requirements for carbon adsorption and incineration systems. Provisions for the potential compliance by use of water-borne and high-solids inks are recommended. The industry is described, methods for reducing organic emissions are reviewed, and monitoring and enforcement aspects are discussed. (22 references.)

62. Pruessner, R. D. and L. D. Broz. Hydrocarbon Emission Reduction Systems. Chemical Engineering Progress, 73(8): 69-73, 1977.

ABSTRACT: This article describes the design and operation of the different types of equipment used to control hydrocarbon emissions in a petrochemical plant. Three incineration, four condensation, and two adsorption systems are discussed. (2 tables, 3 figures.)

63. Hardison, L. C. and E. J. Dowd. Emission Control Via Fluidized Bed Oxidation. Chemical Engineering Progress, 73(8): 31-35, 1977.

ABSTRACT: This article discusses a catalytic incineration system for treating organic emissions that permits lower temperatures and fuel costs than either thermal or flame incineration techniques. The development and the design of a fluidized bed unit are described. (6 references, 6 figures.)

64. Franza, M. E. Controlling Fugitive VOC Emissions from the Metal Finishing Industry. Metal Finishing, 80(12): 39-45, 1982.

ABSTRACT: A study of major industrial surface coating operations has identified manufacturing operations where significant sources of fugitive VOC emissions exist. Four commercially successful control devices are described, which confine and capture the VOC emissions at the source. The use of air curtains with a canopy hood has proved to be technically and economically feasible. The flash-off tunnel is an integral part of the coating and curing equipment in the automobile industry. The use of ventilation and vapor recovery systems is recommended to control the sources of fugitive VOC emissions associated with storage and handling of solvents. Maintenance procedures, economic considerations, and potential energy savings for control devices are discussed. (5 references, 3 tables, 5 figures.)

65. Freidburg, H. R. Survey of VOC Control Methods. Products Finishing (Cincinnati), 46(6): 50-57, 1982.

ABSTRACT: This article examines the materials and methods available for reducing VOC emissions from coating operations. Substitution of coating materials, changing application methods, condensation and incineration of VOC, and carbon absorption are discussed and evaluated. (3 tables, 2 figures.)

66. Darvin, C. H. Emissions from Open Top Vapor Degreasing Systems. In: Third Conference on Advanced Pollution Control for the Metal Finishing Industry, Kissimmee, FL, April 14-16, 1980. EPA 600/2-81-028. U. S. Environmental Protection Agency, Cincinnati, OH, February 1981. pp. 98-101.

ABSTRACT: This paper summarizes a comprehensive testing program which examined the operating conditions that cause VOC emissions from open top vapor degreasers. It concludes that emissions from degreasers can be reduced by employing such simple operating procedures as low hoist speeds, closing of the system lid when in idle condition, and shielding the system from high draft velocities. These changes, however, require a conscious and continuous effort on the part of the operator. Passive control options such as increased freeboard and refrigerated chillers are especially effective and require only installation and maintenance. These operating procedures and design modifications represent relatively inexpensive options and would produce only minor changes in plant operations.

67. Meinke, J. H. American Can's Air Raid Program. In: Proceedings of Paper Synth. Conference, Technical Association of Pulp and Paper Industry, Cincinnati, OH, September 15-17, 1980. TAPPI Press, Atlanta, GA, 1980, pp. 297-300.

ABSTRACT: This paper discusses American Can's program aimed at determining the best technical methods of meeting the EPA solvent emissions requirements for their tinplate coating plants. The program encompasses the following areas: 1) investigation of add-on emission control options and installations; (2) studies of operating parameters for emission control equipment sizing; (3) evaluation of material for alternate technologies; (4) final strategy decision on how to comply with emission standards on each piece of equipment. Add-on control equipment being studied includes incineration, utilizing a pebble bed or catalytic process. Solvent recovery processes being evaluated include the fixed bed, or refrigeration types of systems.

68. Carnes, R. A. and F. C. Whitmore. Hazardous Waste Incineration and Gaseous Waste Pollution Control. In: Proceedings of the Air Pollution Control Association, 72nd Annual Meeting, Cincinnati, OH, June 25-29, 1979. Air Pollution Control Association, Pittsburgh, PA, 1979, Volume 1, Paper 79-5.2. 16p.

ABSTRACT: This paper presents the results of an extensive series of combustion experiments. The experiments involve incineration of PCB-containing capacitor manufacturing waste materials using a prototype incinerator system. Techniques for feed control, for high temperature duct sampling, and for measurement of residence times are illustrated. The relationship between intermediate product production and operating conditions, and the correlation between the proposed CO/CO_2 definition of combustion efficiency and the PCB mass balance, are discussed (6 references, 3 figures.)

69. Ivey, L. R. Evaluation of Air Pollution Control Systems for Volatile Organic Chemicals. Presented at the 180th American Chemical Society National Meeting, San Francisco, CA, August 24-29, 1980, 6p.

ABSTRACT: Four types of ventilation for vapors from surface coating operations are examined. Then the following control systems are discussed: absorption in water; absorption in organic liquids; carbon adsorption; liquid surface adsorption with surfactants; condensation; electrostatic precipitation; noncatalytic incineration; and catalytic incineration. Conditions under which they perform satisfactorily are specified and problems which hinder the effectiveness or practicability of each are outlined.

70. Straitz, J. F. III. Flaring for Gaseous Control in the Petroleum Industry. In: Proceedings of the Air Pollution Control Association, 71st Annual Meeting, Houston, TX, June 25-30, 1978. Air Pollution Control Association, Pittsburgh, PA, 1978. Volume 4, Paper 78-58.8. 12p.

ABSTRACT: The paper illustrates the flaring process with its many applications, types, designs, problems, and questions. Three general types of flares are described and the performance of flares for various process applications is considered. A literature review provides estimates and design procedures for thermal radiation, liquid carry-over, noise and smokeless operation. (13 references, 7 figures.)

71. Teller, A. J. New Systems for Municipal Incinerator Emission Control. In: Proceedings of the 8th Biennial National Waste Processing Conference, Chicago, IL, May 7-10, 1978. American Society of Mechanical Engineers, New York, NY, 1978. pp. 179-187.

ABSTRACT: The operation and characteristics of two new processes for emission control from municipal waste incineration - the chromatographic dry process and ionizing wet scrubbing - are described. These processes have exhibited the capability to simultaneously reduce the concentration of particulates, acid gases, and opacity to less than regulatory limits over a ten-fold variation in inlet conditions. (10 references.)

72. Cowherd, C., M. Marcus, C. Guenther, and J. L. Spigarelli. Hazardous Emissions Characterization of Utility Boilers. EPA-650/2-75-066. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1975. 185p.

ABSTRACT: The report gives results of a field sampling program aimed at quantifying potentially hazardous pollutants in the waste streams of a representative coal-fired utility boiler: a 125-MW boiler (fired with pulverized coal and equipped with a mechanical fly ash collector) at TVA's Widows Creek steam electric generating station. The combustion products identified as potentially hazardous air pollutants included 22 trace elements, nitrates, sulfates, polycyclic organic compounds, and polychlorinated biphenyls. The waste streams sampled included pulverized coal, furnace bottom ash, superheater ash, collection ash, and flue gases at the fly ash collector inlet and outlet. Acceptable mass balance was achieved for about half of the elemental pollutants. Trace metal enrichment was measured. Study results include recommended modifications of sample collection and preparation methods: larger and more frequent samples of coal and bulk ash streams are expected to improve sample representativeness; development of methodologies for estimating bulk ash flows will permit internal checks on mass balances: and routine chemical analysis of NBS standard coal and fly ash will improve quality assurance of the analytical methods.

73. Baig, S., M. Haro, G. Richard, T. Sarro, S. Wolf, T. Hurley, D. Morrison, and R. Parks. Conventional Combustion Environmental Assessment. Draft. EPA Contract No. 68-02-3138. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1981. 464p.

ABSTRACT: This report describes a data base which was developed to provide access to information relating to the environmental effects of stationary conventional process (SCCP) sources. SCCP emission stream characteristics which influence or affect the amount of noncriteria pollutants released to the environment are evaluated. The noncriteria pollutants investigated include benzo(a)pyrene (BaP) and the following trace elements: beryllium, cadmium, chromium, manganese, mercury, molybdenum, nickel, selenium, and vanadium. Nationwide emission totals of noncriteria pollutants from all SCCP sources are presented. Available control systems are discussed and assessed in relation to cost and control efficiency for noncriteria pollutants. Existing methods for rating uncertainty in emission factors are evaluated.

74. Radian Corporation. Locating and Estimating Air Emissions from Sources of Nickel. Draft. EPA Contract No. 68-02-3513, Work Assignment No. 22. Durham, NC, November 1983. 166p.

ABSTRACT: The report serves as a primer to inform air pollution personnel about (1) the types of sources that emit nickel; (2) process variations and release points that may be expected within these sources; and (3) available emissions information indicating the potential for nickel or nickel compounds to be released into the air from each operation. The report provides a brief summary of the physical and chemical characteristics of nickel, its commonly occurring forms, and an overview of its production and uses. Major industrial source categories discharging nickel and nickel compounds are discussed. For each source category, example process descriptions and flow diagrams are given, potential emission points are identified, and available emission factor estimates are presented showing potential nickel emissions before and after controls employed by industry. Available procedures for source sampling and analysis of nickel are summarized.

75. Radian Corporation. Estimates of Population Exposure to Ambient Chromium Emissions. Draft. EPA Contract No. 68-02-3818, Work Assignment No. 2. Durham, NC, August 1983. 184p.

ABSTRACT: The report summarizes the results of a study estimating the potential levels of human exposure to average annual atmospheric concentrations of chromium in the U. S. The major source categories assessed in the report include steel manufacturing, ferrochromium manufacturing, refractory manufacturing, chromium chemicals manufacturing, coal and oil combustion, sewage sludge and municipal refuse incineration, cement manufacturing, chromium ore refining, and cooling towers. The potential national population exposure to chromium was determined using the U. S. EPA Human Exposure Model (HEM). The appendices include a description of the Human Exposure Model (HEM), an evaluation of the source category data for the HEM analysis, and a listing of total chromium concentrations measured in the ambient air of the U. S. during 1977-1980.

76. Tiernan, T. O., M. L. Taylor, J. H. Garrett, G. F. Van Ness, J. G. Solch, D. A. Deis, and D. J. Wagel. Chlorobenzodioxins, Chlorodibenzofurans and Related Compounds in the Effluents from Combustion Processes. Chemosphere, 12(4-5): 595-606, 1983.

ABSTRACT: This paper describes a study to determine the magnitude of CDDs/CDFs emissions from refuse-fueled incinerators. This study involved measuring the entire series of CDDs/CDFs, as well as determinations of related compounds, including chlorophenols, chlorobenzenes, and polychlorinated biphenyls, which may be involved in the formation of CDDs/CDFs under pyrolysis conditions. This paper also reports the results of determinations of CDDs/CDFs in the products from incineration of waste products and compares these with the distribution observed in the waste chemical formulations burned. Finally, initial results obtained in the determination of CDDs/CDFs (and TCDDs in particular) formed in the laboratory pyrolysis of pine wood, in the presence and absence of a chlorine source, are described. (10 references, 11 tables, 4 figures.)

77. GCA Corporation. Survey of Cadmium Emission Sources. EPA-450/3-81-013. U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1981. 157p.

ABSTRACT: The report presents data describing the uses of cadmium, potential sources of cadmium emissions, control techniques, estimated controlled and uncontrolled cadmium emissions, estimated ambient air quality, and compliance status. The results of special dispersion modeling are presented for incineration, interaction of smelters, and for interaction of sources in the New York City - New Jersey area.

78. Hardy, E. R. Phosgene. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 17. John Wiley & Sons, New York, NY, 1982, pp. 416-425.

ABSTRACT: This article discusses the chemical and physical properties of phosgene, its manufacture, and its major uses. It also describes analytical and test methods, storage and handling procedures, and health and safety factors, including waste disposal. (81 references, 2 tables.)

79. Byers, R. L. and T. L. Gage. Multicyclones for Control of Petroleum Coke Emissions. Chemical Engineering Progress, 77(12): 45-51, 1981.

ABSTRACT: This paper presents the results of both a pilot plant study and the performance of a full scale multicyclone unit. The pilot plant tests show that overall mass collection efficiencies as high as 86 percent can be achieved at particulate concentrations ranging from 0.15 to 0.27 gr/dscf (0.35 to 0.62 g/m^3) with mass median particle diameter ranging from 2.5 to

1.7. Corresponding levels of efficiency were achieved by a full-scale unit operating on similar particulate emission characteristics. Plume opacities from the full-scale multicyclone stack ranged from 0-15 percent. (1 reference, 4 tables, 8 figures.)

80. Lebowitz, H. E., S. S. Tam, G. R. Smithson, Jr., H. Nack, J. H. Oxley. Potentially Hazardous Emissions from the Extraction and Processing of Coal and Oil. EPA-650/2-75-038. U. S. Environmental Protection Agency, Research Triangle Park, NC, April 1975. 162p.

ABSTRACT: The report lists potentially hazardous materials which may be associated with the air, water, and solid waste from a refinery, a coke plant, a Lurgi high-Btu gas process, and the solvent refined coal process. Fugitive loss was identified as the major emissions source in the refinery, although its composition is difficult to quantify. Coking is the most offensive of the four processes assessed. Coal gasification may produce materials as dangerous as those from the coke plant, but the former may probably be more contained than coke oven emissions. The environmental impact of coal liquefaction is not well defined; however, liquefaction products will probably be more hazardous than crude oil products, and their refining and utilization will be worse offenders than corresponding petroleum operations.

81. Serth, R. W., D. R. Tierney, and T. W. Hughes. Source Assessment: Acrylic Acid Manufacture; State of the Art. EPA-600/2-78-004W. U. S. Environmental Protection Agency, Cincinnati, OH, August 1978. 83p.

ABSTRACT: This report summarizes data on air emissions from the production of acrylic acid. Hydrocarbons, carbon monoxide and nitrogen oxide are emitted from various operations. Hydrocarbon emissions consist of acetaldehyde, acetic acid, acetone, acrolein, acrylic acid, benzene, phenol, propane, propylene and other materials. To assess the environmental impact of this industry, source severity was defined as the ratio of the time-averaged maximum ground level concentration of a pollutant from a representative plant to the ambient air quality standard (for criteria pollutants) or to a reduced threshold limit value (for noncriteria pollutants). Source severities were not greater than 1.0 for any criteria or noncriteria pollutant. Emissions from acrylic acid plants are not expected to increase in the future as plants are installing incinerators on new plants to control emissions. (68 references, 21 tables, 4 figures.)

82. Carotti, A. A. and E. R. Kaiser. Concentrations of Twenty Gaseous Chemical Species in the Flue Gas of a Municipal Incinerator. Journal of the Air Pollution Control Association, 22(4): 248-253, 1972.

ABSTRACT: Ten tests over a period of six months were conducted at the incinerator plant of the Town of Babylon, Long Island, N.Y. Some of the gaseous chemical species which were collected and analyzed were nitrogen dioxide, acid gases and mists, aldehydes, ketones, sulfur dioxide, hydrocarbons, and phosgene. Scrubber efficiencies were recorded via chloride and hydrogen ion measurements of the collected samples. (5 references, 5 tables, 3 figures).

83. Barrett, R. E., P. R. Webb, E. E. Riley, and A. R. Trenholm. Effectiveness of a Wet Electrostatic Precipitator for Controlling POM Emissions from Coke Oven Door Leakage. In: Proceedings of the Air Pollution Control Association, 71st Annual Meeting, Houston, TX, June 25-30, 1978. Air Pollution Control Association, Pittsburgh, PA, 1978. Volume 1, Paper 78-9.3. 16p.

ABSTRACT: This paper describes results of a coke oven emission measurement program which was conducted as part of the U. S. Environmental Protection Agency's overall program to develop emission factors and emission standards for various industrial processes. The prime objective of this program was the measurement of emissions arising from door leakage during the coking cycle. POM concentrations were measured at the inlet and outlet of a wet electrostatic precipitator (WESP) used to remove pollutants from a coke oven shed exhaust stream, and control device efficiency was determined for total POM, and for 17 specific POM species. (11 references, 5 tables, 2 figures.)

84. McElroy, A. D. and F. D. Shobe. Source Category Survey: Secondary Zinc Smelting and Refining Industry. EPA-450/3-80-012. U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1980. 61p.

ABSTRACT: This report describes the results of a survey of the secondary zinc smelting and refining industry to determine the probable impact of the development of new source performance standards under Section 111 of the Clean Air Act. This industry recovers zinc as metallic zinc, zinc dust, zinc oxide, or zinc alloys from scrap by melting or distillation processes. However, primary zinc smelters and refinerers, who process zinc from ore, were excluded, even though they also process scrap to recover zinc. Information was gathered by collecting process, emission, and economic data from literature searches; contacting air pollution control agencies, other government agencies, industry representatives, and trade associations; and visiting a secondary zinc plant. The report describes the industry, projects production and capacity to 1989, and describes industry processes, actual and allowable air emissions, and emission control systems. State and local emission regulations are compared and the probable impact of a new source performance standard is assessed.

85. Jenkins, R. A., S. K. White, W. H. Griest, and M. R. Guerin. Chemical Characterization of the Smokes of Selected U. S. Commercial Cigarettes: Tar, Nicotine, Carbon Monoxide, Oxides of Nitrogen, Hydrogen Cyanide, and Acrolein (32 Brands). ORNL/TM-8749. Oak Ridge National Laboratory, TN, May 1983. 44p.

ABSTRACT: Thirty-two brands of U. S. commercial cigarettes were analyzed for their deliveries of tar, nicotine, CO, CO_2, HCN, NO_x, and acrolein under standard smoking conditions. Per cigarette and per puff deliveries were calculated. The sample suite contained filtered and nonfiltered cigarettes. The range of deliveries of these constituents was considered. Statistical analysis indicated that the deliveries of nicotine, CO, NO_x, and HCN could usually be estimated to within 50 percent of their actual delivery if the tar delivery was known. However, brand to brand variation in the constituent ratios was sufficient so as to preclude the exact calculation of the delivery of one component from that of another.

86. Menzies, K. T., K. J. Beltis, P. L. Levins, L. H. Sadowski, and B. A. Workman. In-Mine Measurement of Reactive Diesel Exhaust Contaminants. BUMINES-OFR-198-82. Bureau of Mines, Washington, DC, September 1980. 151p.

ABSTRACT: This report documents laboratory and in-mine analyses of diesel exhaust pollutants carried out to assess the fate of potentially reactive species in a mine environment. Specifically, the concentration of stable compounds including nitric oxide, nitrogen dioxide, sulfur dioxide, aldehydes, formaldehyde, acrolein, formic acid, odorants, particulates, soluble sulfates, and polynuclear aromatic hydrocarbons were determined. The concentration and mass emission rates of these compounds were measured in the laboratory under three engine speeds and load conditions and with three exhaust control conditions.

87. Carey, P. M. Mobile Source Emissions of Formaldehyde and Other Aldehydes. EPA/AA/CTAB/PA/81-11. U. S. Environmental Protection Agency, Ann Arbor, MI, May 1981. 37p.

ABSTRACT: The available vehicular aldehyde studies were summarized in an attempt to characterize aldehyde emissions from motor vehicles. Topics covered in these studies include aldehyde emission factors for unmodified and malfunction vehicle engine configurations, effects of fuel, mileage accumulation and temperature variations, and aldehyde emissions from diesel-equipped vehicles equipped with prototype light-duty diesel oxidation catalysts. Thus, it was possible to obtain aldehyde data for standard conditions and for a variety of operating conditions. The Federal test procedure (FTP) was used for the light-duty vehicles and the 13-mode test procedure for the heavy duty engines. The 2, 4 dinitrophenylhydrazine (DNPH) procedure was used for the sampling and analysis of the aldehydes. This procedure is discussed in the Appendix. In addition to aldehydes, the DNPH procedure detects two ketones, methylethylketone and acetone. Methylethylketone measurements are not included in this report. However, acetone and two aldehydes, acrolein and propionaldehyde, are reported together as acetone since they are not resolved from each other under normal gas chromatographic operation conditions. The term "total aldehydes" as used in this report includes the acetone measurements.

88. Springer, K. J. Baseline Exhaust Emissions from U. S. Army M54A2 Lds 465 Powered Five-Ton Trucks. SWR1-AR-690. Southwest Research Institute, San Antonio, TX, April 1969. 45p.

ABSTRACT: Baseline exhaust emissions data were obtained as part of a 20,000 mile test of lube oils in four M54A2 five-ton Army trucks powered by the LDS 465 turbocharged, four-cycle, compression ignition engine. These emissions include odor, smoke and chemical/instrumental measurements of total nitric oxide, total aliphatic aldehydes, formaldehyde, acrolein and sulfur dioxide using the latest techniques available. Power checks as well as emissions were obtained at the beginning, end, and at about 6,500 and 12,000 mile duration. The effects of vehicle operating condition and test mileage are presented as part of the analysis of the results. Typical data for two widely used, commercial truck-tractors powered by four-cycle, naturally aspirated and turbocharged engines are indicated to place the military truck emissions in perspective. Limited back-to-back type operation of two vehicles on a commercial barium smoke suppressant fuel additive was conducted periodically and the constant and transient smoke results are presented. In addition to summary and conclusions, recommendations are made to learn more about exhaust emissions from vehicles in the current and future Army inventory.

89. Pelizzari, E. D. Quantification of Chlorinated Hydrocarbons in Previously Collected Air Samples. EPA-450/3-78-112. U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1978. 151p.

ABSTRACT: Selected "volatile" chlorinated hydrocarbons were quantified in more than 250 ambient air samples from 28 U. S. cities representing 10 states. Examination of the data reveals that their occurrence in the atmosphere may be regarded as either ubiquitous or site specific. Some of the representative ubiquitous halogenated compounds are methylene chloride, chloroform, carbon tetrachloride, 1,1-dichloroethane, 1,2-dichloroethane, trichloroethylene, chlorobenzene, tetrachloroethylene, dichlorobenzene isomers, and methyl chloroform.

90. Weiland, J. H. Control of Fugitive Emissions in Petroleum Refining. In: Symposium on Fugitive Emissions Measurement and Control, Hartford, CT, May 17-19, 1976. EPA-600/2-76-246. U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1976. 8p.

ABSTRACT: In this paper, fugitive emissions are defined as any emissions which are not released through a stack or duct. Under this definition, volatile hydrocarbons are the primary fugitive emissions of concern in petroleum refining. This paper reviews some of the emission sources, discusses briefly the emission factors that are commonly used to attempt to get some fix on these emissions, and then describes some of the control methods that may be used.

91. Krieve, W. F. and J. M. Bell. Charged Droplet Scrubber for Fine Particle Control: Pilot Demonstration. EPA-600/2-76-249b, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1976. 88p.

ABSTRACT: The report gives results of a successful Charged Droplet Scrubber (CDS) pilot demonstration of coke oven emissions control. It also describes the design, installation, and checkout of the demonstration system. The CDS uses electrically sprayed water droplets, accelerated through an electric field, to remove particulate material from a gas stream. The pilot demonstration was a continuation of laboratory and bench scale studies for application of the CDS to fine particle control. The pilot demonstration included, in addition to the CDS, the ducting, flow transitions, and blower necessary to circulate process gas through the CDS. The test was performed at the Kaiser Steel Company coke oven facility, Fontana, California. A large fraction of the coke oven emissions were submicron and composed of carbon particles and hydrocarbon aerosol. After the system checkout was completed, during which CDS operating parameters were established, the demonstration test series was performed. Results of the demonstration test indicate that the CDS is an effective pollution control device for controlling coke oven stack emissions.

92. Bee, R. W., G. Erskine, R. B. Shaller, R. W. Spewak, and A. Wallo, III. Coke Oven Charging Emission Control Test Program. Volume I. EPA-650/2-74-062. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1974. 181p.

ABSTRACT: The report summarizes results of a coke oven charging emission control test program conducted at the P4 Batter of the Jones and Laughlin Pittsburgh Works between April 1971 and May 1974; actual field testing was between May and August 1973. Objectives of the test program were to quantify atmospheric pollutants resulting from the coking process charging operation; to provide a comparative evaluation of a pollution abatement system (an improved design larry car versus an existing larry car); and to determine the feasibility of a compliance monitoring system concept based on optical measurement. All program objectives were accomplished; emission characteristics of the charging operation were defined in terms of both gases and particulates released to the atmosphere. Emissions were also defined from leaking seals on the pushed side doors of the oven. Several pertinent conclusions were also developed relating to coke oven emission measurement technology.

93. Coke Oven Air and Water Pollution. 1970 - July 1982 (Citations from the Engineering Index Data Base). PB82-811076. National Technical Information Service, Springfield, VA, August 1982. 234p.

ABSTRACT: Monitoring, sampling, analyzing, transport properties, and control of emissions and effluents are cited in this compilation from worldwide journals. Pollutants described are sulfur dioxide, hydrogen sulfide, ammonia, phenols, benzopyrene, particulates and other trace elements and compounds. Process and equipment modifications, such as pipeline charging, wet and dry quenching, retrofitting, and oven leakage preventives are included. (This updated bibliography contains 227 citations, 17 of which are new entries to the previous edition.)

94. National Research Council. Kepone/Mirex/Hexachlorochloro-cyclopentadiene: An Environmental Assessment. U. S. Environmental Protection Agency, Washington, DC, 1978. 84p.

ABSTRACT: This report's assessment of the scientific and technical knowledge about the effects of Kepone, Mirex, and Hex as environmental pollutants is based primarily on two literature surveys prepared for the EPA's Office of Research and Development by Battelle Columbus Laboratories and the Stanford Research Institute. The principal findings and research needs arising from the panel's assessment are summarized. Documentation for the findings can be found in the body of the report as noted parenthetically after each finding. The list of research needs identifies areas where more knowledge is needed before a truly comprehensive assessment of the effects of Kepone, Mirex, and Hex can be made.

95. Roundbehler, D. P. and J. Fajen. Survey for N-Nitroso Compounds at A. C. Lawrence Tannery, S. Paris, Maine. National Institute for Occupational Safety and Health, Cincinnati, OH, August 1978. 29p.

ABSTRACT: An industrial hygiene survey was conducted at A. C. Lawrence Tannery (SIC-3111) in South Paris, Maine on April 11 and 13 and June 1, 1978 to determine work exposure to N-nitroso compounds. Nitrosodimethylamine (62759) (NDMA) was found in all air samples taken inside the facility and ranged from nondetectable outside the facility to 47 micrograms per cubic meter at the retanning area. The average atmospheric NDMA concentration was 13 micrograms/cu m. Several samples also contained unreported concentrations of N-nitrosomorpholine (59892). The author recommends that this tannery be reexamined and other tanneries be surveyed to determine an industry profile.

96. Timm, C. M. Sampling Survey Related to Possible Emission of Polychlorinated Biphenyls (PCBs) from the Incineration of Domestic Refuse. PB-251 285. U. S. Environmental Protection Agency, Chicago, IL, November 1975. 53p.

ABSTRACT: During the three-week period October 20-November 7, 1975, ambient and stack sampling for polychlorinated biphenyls (PCBs) were conducted at a domestic incinerator in an effort to quantify the levels of PCB emissions associated with the incineration of domestic refuse. The stack sampling was performed at an incinerator equipped with an electrostatic precipitator using a modified EPA Method 5 sampling train. Xylene was used as the solvent for any gaseous PCBs present in the effluent. Ambient sampling was conducted, upwind and downwind of the incinerator, using hexane as the solvent in duplicate sets of three impingers in series. The following conclusions were drawn: the particulate emissions contained PCBs, but, the amount emitted did not result in a measurable increase in existing ambient levels of PCB; the presence of PCBs in the vapor state could not be established because of contamination in the xylene used as the solvent; and the use of hexane as the absorbing reagent was appropriate for ambient sampling.

97. Schwartz, W. A., F. B. Higgins, Jr., J. A. Lee, R. B. Morris, and R. Newrith, Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry. Volume 7: Phthalic Anhydride Manufacture from Ortho-xylene. EPA-450/3-73-006g. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1975. 108p.

ABSTRACT: This document is one of a series prepared for the Environmental Protection Agency (EPA) to assist it in determining those petrochemical processes for which standards should be promulgated. A total of nine petrochemicals produced by twelve distinctly different processes has been selected for this type of in-depth study. A combination of expert knowledge and an industry survey was used to select these processes. This volume covers the manufacture of phthalic anhydride from ortho-xylene. Included is a process and industry description, an engineering description of available emission control systems, the cost of these systems, and the financial impact of emission control on the industry. Also presented are suggested air episode procedures and plant inspection procedures.

98. Process Research, Inc. Air Pollution from Chlorination Processes. APTD-1110. U. S. Environmental Protection Agency, Cincinnati, OH, March 1972. 172p.

ABSTRACT: Industrial use of chlorine is growing at a rapid rate. About 3.0 percent of the total is used for water sanitation and 16.0 percent is consumed in the pulp and paper industry. The balance of 81.0 percent is used in the production of chlorinated hydrocarbon products. Because of the apparent potential for atmospheric pollution with chlorine, hydrochloric acid and various hydrocarbon compounds, a survey of the processes employed for the production of 16 most important chlorinated hydrocarbon products was undertaken. Past, present, and projected production figures for these materials are shown and an analysis of processes is reported. The sixteen major products studied include: carbon tetrachloride; chloroform; epichlorohydrin; ethyl chloride; 1,2-dichloroethane; allyl chloride; hydrogen chloride; methyl chloride; methylene chloride; monochlorobenzene; phosgene; propylene oxide; tetrachloroethylene; 1,1,1-trichloroethane; 1,1,2-trichloroethylene; and vinyl chloride.

99. Proceedings: First Symposium on Iron and Steel Pollution Abatement Technology, Chicago, IL, October 30-November 1, 1979. EPA-600/9-80-012, U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1980. 513p.

The symposium was organized into air, water, and solids sessions. Air pollution topics included: emission standards, assessment of coke quench tower and byproduct recovery plant emissions, sealing of coke-oven doors, volatilization of hydrocarbons in steel rolling operations, development of a coke-oven air pollution control cost-effectiveness model, control of sinter plant emissions utilizing recirculation of windbox gases, estimating fugitive contributions to ambient particulate levels near steel mills, foreign technology for BOF fugitive emission control, and fugitive particulate emission factors for BOF operations. Water topics included emission standards, total recycle of water in integrated steel mills, use of spent pickle liquor in municipal sewage treatment, physical/chemical treatment of steel plant wastewaters using mobile pilot units, foreign technology for controlling coke plant and blast furnace wastewaters, and formation and structure of water-formed scales. Solid waste topics included emissions standards, environmental and resource conservation considerations of steel industry solid waste, and de-oiling and utilization of mill scale.

100. Hoffman, A. O., A. T. Hopper, and R. L. Paul. Development and Demonstration of Concepts for Improving Coke-Oven Door Seals. EPA-600/2-82-066. U. S. Environmental Protection Agency, Research Triangle Park, NC, April 1982. 112p.

ABSTRACT: The report discusses the design, laboratory scale tests, construction, and field tests of an improved metal-to-metal seal for coke-oven end doors. Basic features of the seal are: high-strength temperature-resistant steel capable of three times the deflection of current seals without permanent deformation; no backup springs and plungers and the attendant requirement for manual inservice adjustments; seal installed to conform to the jamb profile; seal lip height reduced to give eight times the inplane flexibility; and compatibility with existing coke batteries and door handling machines.

101. Mutchler, J. E., T. A. Loch, F. I. Cooper, and J. L. Vecchio. Source Testing of a Stationary Coke-Side Enclosure. Great Lakes Carbon Corporation, St. Louis, Missouri Plant. Volume I. EPA-340/1-77-014a. U. S. Environmental Protection Agency, Washington, DC, August 1977. 120p.

ABSTRACT: This report summarizes a study of coke-side emissions at three coke-oven batteries producing foundry coke at Great Lakes Carbon Corporation (GLC) in St. Louis, Missouri. Of the three batteries, the south battery "A" is equipped with the coke-side shed. The center battery "B" and the north battery "C" were not equipped with a functional shed at the time of the study. Objectives of this study were to develop: (1) basic engineering data concerning process emissions, fugitive emissions from the shed, capture efficiency of the shed, and quantity and characteristics of contaminants present in the shed exhaust; (2) other basic engineering data for specification of future retrofitted control devices for specification of future retrofitted control devices for removal of air contaminants in the shed exhaust; and (3) correlations to relate these measurements to process conditions.

102. Mobley, C. E., A. O. Hoffman, and H. W. Lownie. Sealing Coke-Oven Charging Lids, Chuck Doors, and Standpipe Elbow Covers: Survey of Current U. S. State of the Art. EPA-600/2-77-058. U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1977. 21p.

ABSTRACT: The report gives results of a survey of the current U. S. state-of-the-art approach and methodology for sealing coke-oven charging lids, chuck doors, and standpipe elbow covers. The study was part of the program "Technical Support for U. S./U.S.S.R Task Force on Abatement of Air Pollution from the Iron and Steel Industry." The survey concluded that: (1) seals associated with coke-oven charging lids, chuck doors, and standpipe elbows covers are all metal-to-metal contact; (2) charging lids and standpipe elbow covers are typically flat, tapered, or shouldered surface contacts, but chuck-door seals are similar to end-closure door seals (i.e., metal strips pressured against a flat metal surface); (3) oven designers indicate that all three components should provide an emission-proof seal, if properly cleaned and maintained; and (4) U. S. coke plant operations augment the inherent seal of these components with luting mud, slurries, and/or gaskets. The study did not develop data relating the extent and type of emissions from these components.

103. Lownie, Jr., H. W. and A. O. Hoffman. Study of Concepts for Minimizing Emissions from Coke-Oven Seals. EPA-650/2-75-064. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1975. 235p.

ABSTRACT: The report gives results of a study aimed at minimizing emissions from coke-oven door seals. It identifies problems associated with the sealing of slot-type coke oven and closures, and quantifies them to a limited degree by test results presented in the report. It analyzes coke-oven door sealing systems -- those which have been developed in the past, as well as those currently in use -- with respect to individual strengths and weaknesses. It develops and critically analyzes concepts to improve the seal design, and recommends the development of the two most favorable concepts.

104. McClelland, R. O. Coke Oven Smokeless Pushing System Design Manual. EPA-650/2-74-076. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1975. 56p.

ABSTRACT: The report describes the design and operation of a system to eliminate atmospheric emissions during the pushing of coke from the 45-oven A-battery at Ford Motor Co.'s Rouge Plant in Dearborn, Michigan. The 10-year-old A-battery consists of 45 13-ft high ovens, each producing 12 tons of blast furnace coke at a gross coking time of 18 hours with a "push" scheduled each 15 minutes. The Coke Guide Fume Hood, where the entire coke guide is enclosed with a hood that extends out over the quench car, was used to eliminate the pushing emissions. Prior to the push, the hood is connected to a stationary fume main that is under partial vacuum; the hot coke emissions generated during the push are conveyed to a high-energy wet-type gas scrubber where the gas stream is cleaned before being emitted to the atmosphere. Clearances between the hood and quench car are held to a minimum to provide sufficient indraft velocities to overcome normal lateral wind effects.

105. Bee, R. W. and R. W. Spewak. Coke Oven Charging Emission Control Test Program. Supplemental Observations. EPA-650/2-74-062a. U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1974. 120p.

ABSTRACT: The report compares operational information for two coke charging cars operating to reduce charging emissions from the Brown's Island battery of National Steel's Weirton Steel Division with that for a larry car developed jointly by the American Iron and Steel Institute (AISI) and the U. S. Environmental Protection Agency. A direct comparison is made in areas where similarities between the two designs is strong; in areas with contrasting features or procedures, their success is reported relative to design intent and the EPA objectives. Facts presented by the report originated in three areas: a description of the Weirton coking system, including oven configuration, larry car operation, and general coke oven charging procedures; observation of the two Weirton larry cars during coal charging operation; and interviews with coke plant personnel responsible for operating the larry cars.

106. Stoltz, J. J. Coke Charging Pollution Control Demonstration. EPA-650/2-74-022. U. S. Environmental Protection Agency, Washington, DC, March 1974. 327p.

ABSTRACT: The report gives results of demonstrating a coke oven charging system designed to reduce emissions sufficiently to both meet future air pollution control requirements and improve the environment on top of the battery for operating personnel. The work included detailed engineering, construction, and testing of a prototype system on an existing battery with a single gas collecting main. The demonstration showed that, although emissions were reduced significantly, the system must be modified with a double gas off-take to satisfy air pollution control requirements. The system can be applied to new batteries or to existing batteries where a double gas off-take exists or can be obtained by such means as a second collecting main or jumper pipes.

107. Wittman, S., B. Arnold, W. Downs, and P. Smith. A Selected Bibliography of Public Information Materials about Polychlorinated Biphenyls (PCBs). NOAA-81041303. National Oceanic and Atmospheric Administration, Rockville, MD, February 1981. 16p.

ABSTRACT: This annotated bibliography of PCB-related publications was compiled as a public information service by the communications staff of the University of Wisconsin Sea Grant Institute. These materials are grouped by agencies and organizations and are divided into two categories: brochures, articles and pamphlets for the general public, and more technical publications that provide in-depth background information on the subject. Al the materials described in this booklet are currently available from the organizations listed.

108. Collins, P. F., and G. F. Hunt. Evaluation of PCB Destruction Efficiency in an Industrial Boiler: Audit Report. EPA-600/2-81-055B, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1981. 35p.

ABSTRACT: The report gives results of systems audits and an evaluation of the quality of data obtained by GM and GCA in the analysis of a test burn oil for PCB conducted by Research Triangle Institute. Audits included inspection of documentation and records, discussion of analytical methodology and data with personnel of the organization being audited, and independent data reduction. The analytical data reported by GM and GCA were subsequently confirmed by separate analyses by the EPA's Health Effects Research Laboratory (RTP) and are reported in Appendix A.

109. Ackerman, D. G., L. L. Scinto, P. S. Bakshi, R. G. Delumyea, and R. J. Johnson. Guidelines for the Disposal of PCBs (Polychlorinated Biphenyls) and PCB Items by Thermal Destruction. EPA-600/2-81-022. U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1981. 319p.

ABSTRACT: The report is a resource and guidelines document to aid the EPA Regional Offices in interpreting and applying polychlorinated biphenyl (PCB) regulations to the thermal destruction of PCBs. As background material, the report describes fundamental processes of combustion, thermal destruction systems, sampling and analysis methodology, and flame chemistry relative to PCB incineration. Administrative considerations, including public involvement, are discussed. Detailed guidelines on the evaluation of Annex I incinerators, high efficiency boilers, and the several stages of the approval process are presented and discussed.

110. Flynn, N. W. and C. D. Wolbach. Disposal of Polychlorinated Biphenyls (PCBs) and PCB-Contaminated Materials. Volume 4: Test Incineration of Electrical Capacitors Containing PCBs. EPRI-FP-1207(V.4). Electric Power Institute, Palo Alto, CA, September 1980. 152p.

ABSTRACT: This report presents the results of a trial burn conducted at the Energy Systems Company (ENSCO) located in El Dorado, Arkansas in order to determine whether liquid PCBs and shredded electronic capacitors could be incinerated in accordance with the recent the EPA rules and regulations published in the Federal Register (40 CFR Part 761, Vol. 44, No. 106, pp. 31513-31568, May 31, 1979). Based on the results of this trial burn, PCBs were not detected in the stack effluent, the scrubber liquor effluent, or the recycled scrubber liquor from the sludge lagoon. PCBs were detected in the ash effluent from the rotary kiln and were less than 550 ppm, the lower limit at which PCBs are regulated by the EPA. A discussion is given of problems associated with the EPA perchlorination procedure for analyzing PCBs.

111. Junk, G. A. and C. S. Ford. Review of Organic Emissions from Selected Combustion Processes. IS-4727. U. S. Department of Energy, Washington, DC May 1980. 50p.

ABSTRACT: The 309 organic compounds reported in the literature as emissions from selected combustion processes are tabulated, with 109 originating from coal combustion, 213 from waste incineration, and 69 from coal/refuse combustion. The largest percentage of components have been reported to be present in the grate ash from coal combustion, in the stack emissions from waste incineration, and in the fly ash from coal/refuse combustion. Quantitative data for specific compounds are very incomplete, even for the more common components such as polycyclic aromatic hydrocarbons and polychlorinated biphenyls.

112. Ackerman, D., J. Clausen, A. Grant. R. Johnson, and C. Shih. Destroying Chemical Wastes in Commercial Scale Incinerators. EPA-530/SW-155c. U. S. Environmental Protection Agency, Washington, DC, 1978. 130p.

ABSTRACT: The report summarizes the results of a Phase II test program demonstrating the effectiveness of thermal destruction of industrial wastes in commercial scale facilities. Phase I was a study effort to select and match suitable wastes and destruction facilities, and to develop a set of detailed facility test plans. Phase II evaluated the environmental, technical, and economic feasibility of thermally destroying 14 selected industrial wastes in seven different existing commercial scale processing facilities. Results indicated that each of the wastes tested can be thermally destroyed at high efficiencies. Separate detailed reports published for each facility test series conducted and the two-volume Phase I report are listed in the references.

113. Ackerman, D., J. Clausen, A. Grant, R. Tobias, and C. Zee. Destroying Chemical Wastes in Commercial Scale Incinerators. Facility Report No. 6. Rollins Environmental Service, Inc., Deer Park, TX. EPA/SW-122c.5. U. S. Environmental Protection Agency, Washington, DC, 1977. 173p.

ABSTRACT: Incineration tests were conducted at Rollins Environmental Services, Inc., Deer Park, Texas, to determine the effectiveness of thermally destroying two selected industrial wastes: PCB-containing capacitors and nitrochlorobenzene waste (NCB). Analysis of combustion gas samples indicated destruction efficiencies of over 99.999 percent for each waste constituent. Some PCBs were detected in the ash when whole capacitors were incinerated in the rotary kiln, but not when hammermilled capacitors were burned. Standard EPA Method 5 tests were performed on stack emissions to determine particulate loading and composition. Estimated costs to hammermill and incinerate 5000 metric tons of waste capacitors per year is \$3.65 capital investment and an operating cost of \$751/metric ton. Cost of incinerating 4540 metric tons/year of NCB was estimated to be \$2.82 million capital and \$283/metric ton operating costs.

114. Compliance Status of Major Air Pollution Facilities. EPA-340/1-76-010. U. S. Environmental Protection Agency, Washington, DC, December 1976. 586p.

ABSTRACT: The information listed in this report was produced by the U. S. Environmental Protection Agency's Compliance Data System (CDS) which is operated and maintained by the Agency's regional offices and the Office of Enforcement in headquarters. The facilities listed do not represent a complete listing of all facilities subject to federally-approved or promulgated air pollution regulations but do represent a reasonably complete listing of large sources identified to date by the States and the EPA. There are three parts to this listing: major air pollution facilities subject to state implementation plan (SIP) requirements; air pollution facilities subject to Federal new source performance standards (NSPS); and air pollution facilities subject to Federal hazardous pollutant emission requirements (NESHAPS).

115. Goldberg, A. J. A Survey of Emissions and Controls for Hazardous and Other Pollutants. EPA-R4-73-021. U. S. Environmental Protection Agency, Washington, DC, February 1973. 185p.

ABSTRACT: A preliminary analysis was undertaken to prepare a control technology development plant for air pollution problems facing industry. A literature search was completed (with 144 references) to estimate toxicity levels of 18 pollutants, and the magnitude of emissions from industrial emitter types or classes of emitting processes. A review of control methods organized by pollutants as well as industry, offensive trades (animal processing), food industry (brewery and cannery), chemical industry (paint and rubber), metal industry (foundry and metal coating), other (paper textile, cement, etc.) is included. Minimum controls were often reported where sites were remote to populated areas. Emission hazard data is presented in 14 tables and appendices. Flow charts indicate emission allocations in major areas of processing. Identification and emission points are shown for principal emitting processes. The survey recommends that new R and D should focus on control of nonferrous emitters, heat and energy generating sources, open mining milling and materials handling as well as several lesser industrial sources, particularly those emitting large amounts of fine particulate material (less than 2 micron diameter particles).

116. Chlorine and Air Pollution: An Annotated Bibliography. AP-99. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1971. 108p.

ABSTRACT: A compilation of approximately 162 abstracts of documents and articles on chlorine is presented. These abstracts cover the following categories of air pollution information: emission sources; atmospheric interaction; measurement methods; control methods; effects-human health; effects-plants and livestock; effects-materials; air quality measurement; standards and criteria; basic science and technology.

117. Troxler, W. L., C. S. Parmele, D. A. Barton, and F. D. Hobbs. Survey of Industrial Applications of Vapor-Phase Activated-Carbon Adsorption for Control of Pollutant Compounds from Manufacture of Organic Compounds. EPA-600/2-83-035. U. S. Environmental Protection Agency, Cincinnati, OH, April 1983. 53p.

ABSTRACT: This study covers industrial use of activated carbon for vapor-phase applications. A listing of over 700 applications of vapor-phase carbon systems is made available for use in identifying sites where a given compound is being removed.

118. Sittig, M. Handbook of Toxic and Hazardous Chemicals. Noyes Data Corporation, Park Ridge, NJ, 1981. 729p.

ABSTRACT: This handbook provides brief information on physical properties, potential exposures, permissible exposure limits in air and water, determination in air and water, routes of entry, harmful effects and symptoms, and safety and handling procedures for a large number of chemicals.

119. Price J. H. and J. O. Ledbetter. The Comparative Cost Effectiveness of Reducing Public Exposure to Carcinogens by Abating Chemical Plant Emissions. In: Proceedings of the Air Pollution Control Association, 76th Annual Meeting, Atlanta, GA, June 19-24, 1983. Air Pollution Control Association, Pittsburgh, PA, 1983. Paper 83-6.4. 15p. (10 references, 3 tables.)

ABSTRACT: This study examines the feasibility and cost effectiveness of reducing public exposure to carcinogens by reducing carcinogenic emissions from existing chemical plant vents. These costs are compared to those of controls typically applied to new sources of VOC emissions and to those of reducing public exposure to carcinogens through air, food, or drinking water. This study was conducted in Harris County, Texas, which contains the City of Houston, because: (1) it contained many synthetic organic chemical plants with large production capacities; (2) emission inventory data were available on chemical plant vents; (3) county population distribution data were available. (10 references, 3 tables)

120. Nagda, N. L., D. J. Pelton, and J. L. Swift. Emission Factors and Emission Inventories for Carcinogenic Substances. In: Proceedings of the Air Pollution Control Association, 72nd Annual Meeting, Cincinnati, OH, June 24-29, 1979. APCA, Pittsburgh, PA, 1979. Paper 79-3.1. 15p.

ABSTRACT: This study reports on the estimation of emissions from point and area sources in the Detroit metropolitan area for certain carcinogens--benzo-a-pyrene, nickel, and trichloroethylene. Emission-factor information for such substances is scarce. This study combines information available from several sources and converts such information into a standard format consistent with Michigan Department of Natural Resources data system. Emissions are estimated based on these emission factors, plant operating data, and control efficiency considerations. An indirect validation of the inventories based on these emission factors, plant operating data, and control efficiency considerations. An indirect validation of the inventories based on dispersion modeling studies and comparison with air quality data shows good results. These first-generation estimates on community exposure to carcinogens have been useful as input to a followup epidemiologic study of the area. (11 references, 3 tables, 5 figures.)

121. Jonsson, J. Trends of Fume Control for Iron and Steel Industry - Current and Future. In: Proceedings of the Air Pollution Control Association, 72nd Annual Meeting, Cincinnati, OH, June 24-29, 1979. Air Pollution Control Association, Pittsburgh, PA, 1979. Paper 79-32.2. 15p.

ABSTRACT: This paper describes several methods which are presently used for fume capture - direct extraction, full roof hood, side draft hood, canopy hood - none of which are universally satisfactory. The author contends that a combination of canopy hood with direct extraction is probably the best solution today. The author envisions that future fume control systems will form an integral part of the furnace itself, without interference with metallurgical performance. Two recent Swedish installations, which are good examples of modern, integrated fume control systems, are described. (12 figures)

122. Hendriks, R. V., A. H. Laube, and H. J. Griffin. Organic Air Emissions from Coke Quench Towers. In: Proceedings of the Air Pollution Control Association, 72nd Annual Meeting, Cincinnati, OH, June 24-29, 1979. Air Pollution Control Association, Pittsburgh, PA, 1979. Paper 79-39.1. 16p.

ABSTRACT: This paper presents the results of a 1977 field study, which was undertaken to define quench tower organic emissions. Sufficient stack samples were taken under controlled conditions of coke and quench water quality to provide a statistically confident basis for emission factor determination. The collected samples were subjected to extensive organic chemical analysis for identification and quantification of similar functional groups and selected individual compounds known or expected to be carcinogenic. Fifty-three different organic compounds were found in the quench tower emissions; seven of these were found in sufficient quantity to be considered potential health hazards. The use of wastewater from other coke plant sources for quenching greatly increased the organic load when compared to quenching with river water. Although the water itself was the principal source of organic emissions, the coke also appeared to contribute. Since the majority of organics detected were either gaseous or associated with small particles, they contributed to ambient air contamination beyond plant boundaries. This information provides a basis for developing a control strategy and control technology for the quench tower source.

123. Gordon, R. J. Survey for Airborne Nitrosamines for Two California Counties. In: Proceedings of the Air Pollution Control Association, 72nd Annual Meeting, Cincinnati, OH, June 24-29, 1979. Air Pollution Control Association, Pittsburgh, PA, 1979. Volume 4, Paper 79-59.6. 15p.

ABSTRACT: This paper discusses a survey for airborne volatile nitrosamines, which was conducted in Los Angeles and Contra Costa Counties, California. A mobile sampling unit with ambient aqueous KOH bubblers was used, followed by extraction, concentration, and analysis by gas chromatography with thermal energy analysis detection. The detection was based on decomposition of nitrosamines to NO which gives chemiluminescence upon reacting with ozone. Low levels of dimethyl and diethylnitrosamine were observed sporadically at numerous locations but gave no clear indication of significant point sources. Most samples were below 0.03 ug/m^3, while the highest reached 1.0 ug/m^3. Temporal patterns showed morning and evening maxima and suggested photolysis in midday sun. No relationship between airborne nitrosamine levels by area and incidence of several human cancers was apparent. (12 reference, 1 table, 4 figures.)

124. O'Leary, D. T., K. M. Richter, P. A. Hillis, P. H. Wood, and S. E. Campbell. Methodology for Estimating Environmental Loadings from Manufacture of Synthetic Organic Chemicals. EPA-600/3-83-064. U. S. Environmental Protection Agency, Athens, GA. August 1983. 592p.

ABSTRACT: A methodology is presented for estimating the multimedia environmental loadings for a "new" chemical, in the absence of manufacturing plant emission data. The methodology draws on an environmental release data base that contains unit processes multimedia environmental loadings for structurally similar compounds that undergo similar process (physical and chemical) unit operations. The data base is integrated with other pertinent available data on the manufacturing process of the new chemical such as (1) physical and chemical properties and process feedstock, products and byproducts; (2) reaction stoichiometry, thermodynamics and reaction kinetics; (3) process flow diagram and process mass balance; (4) location and composition of environmental releases and method of disposal; (5) process environmental control technology (including performance); (6) process storage and handling requirements; and (7) plant equipment components (in numbers and classes). In practice, sufficient direct data are rarely available for estimating the environmental loadings of the compounds under review; the methodology has been designed with this reality in mind. In every case, where data deficiencies are likely to occur, alternative means are suggested for filling the data gaps. The methodology integrates all pertinent data to enable the user to estimate multimedia (controlled and uncontrolled) environmental loadings under the classifications of storage and handling, process, and fugitive emissions, respectively. An example is provided to demonstrate the applicability of the methodology.

125. Air Oxidation Processes in Synthetic Organic Chemical Manufacturing Industry - Background Information for Proposed Standards. EPA-450/3-82-001a. U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1983. 547p.

ABSTRACT: Standards of performance for the control of emissions from air oxidation processes in the synthetic organic chemical manufacturing industry are being proposed under the authority of Section 111 of the Clean Air Act. These standards would apply to new, modified, and reconstructed air oxidation facilities. This document contains background information and environmental and economic impact assessments of the regulatory alternatives considered in developing proposed standards.

126. Schwinn, D. E., D. F. Storrier, R. J. Moore, and W. S. Carter. PCB Removal by Carbon Adsorption. Pollution Engineering, 16(1): 20-21, 1984.

ABSTRACT: This paper describes PCB removal by carbon adsorption at a fire training facility operated by an electric utility company. The paper briefly reviews the results of laboratory testing, discusses design constraints, describes the facilities, and offers operation and management guidelines. (1 figure.)

127. Hughes, T. W., D. R. Tierney, and Z. S. Khan. Measuring Fugitive Emissions from Petrochemical Plants. Chemical Engineering Progress, 75(8): 35-39, 1979.

ABSTRACT: This paper describes a study that identified and quantified fugitive emissions from various petrochemical plant processes. Fugitive emissions from petrochemical plants are generally lower when compared to EPA data on fugitive emissions from petroleum refineries. Physical differences in operating conditions and process materials show no relationship on variations in emission rates from individual sources. (4 references, 5 tables, 3 figures.)

128. Compilation of Air Pollutants Emission Factors. Third Edition. Supplement No. 14. AP-42-SUPPL-14. U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1983. 172p.

ABSTRACT: In this supplement of AP-42, new or revised emissions data are presented for Anthracite Coal Combustion, Wood Waste Combustion in Boilers; Residential Fireplaces; Wood Stoves; Open Burning; Large Appliance Surface Coating; Metal Furniture Surface Coating; Adipic Acid; Synthetic Ammonia; Carbon Black; Charcoal; Explosives; Paint and Varnish; Phthalic Anhydride, Printing Ink; Soap and Detergents; Terephthalic Acid; Maleic Anhydride; Primary Aluminum Production; Iron and Steel Production; Gypsum Manufacturing; Construction Aggregate Processing; Sand and Gravel Processing; Taconite Ore Processing; Western Surface Coal Mining; Fugitive Dust Sources; Unpaved Roads; Agricultural Tilling; Aggregate Handling and Storage Piles; and Industrial Paved Roads.

129. Fine, D. H. and U. Goff. Nitrosamine Analysis of Diesel Crankcase Emissions. EPA-460/3-81-008. U. S. Environmental Protection Agency, Ann Arbor, MI, March 1980. 220p.

ABSTRACT: The main objective of this work was to qualify and employ artifact-free methods in the testing of crankcase emissions of heavy-duty diesel engines for volatile N-nitrosamines. The following tasks were performed to achieve this objective: (1) sampling and analysis method development and qualification; (2) engine selection; (3) engine testing; (4) oil analysis method development; (5) selection and survey of oil samples; (6) oil nitrosation method development; (7) survey of the nitrosability of the oils. Sources of the crankcase emission nitrosamines were sought.

130. Singh, H. B., L. J. Salas, R. Stiles, and H. Shigeishi. Measurements of Hazardous Organic Chemicals in the Ambient Atmosphere. EPA-600/3-83-002. U. S. Environmental Protection Agency, Research Triangle Park, NC., March 1983. 99p.

ABSTRACT: Analytical methods were refined and applied to the ambient analysis of 44 organic chemicals, many of which are bacterial mutagens or suspected carcinogens. On-site field collection programs, based on single site studies of 9 to 11 days duration each, were conducted in 10 U. S. cities. Field studies were performed with an instrumented mobile laboratory. A round-the-clock measurement schedule was followed at all sites. The field measurements allowed a determination of atmospheric concentrations, variabilities, and mean diurnal behaviors of the chemicals. The data were analyzed relative to theoretically estimated removal rates. Typical diurnal profiles show highest concentration of the primary pollutants during nighttime or early morning hours, with minimum concentration in the afternoon hours. Chemistry plays only a nominal role in defining this diurnal behavior in most cases. Except for aromatic hydrocarbons and aldehydes, average concentrations of the measured species were in the 0- to 5-ppb range. The average concentration range observed for aromatics and aldehydes was 0- to 20-ppb.

131. Chi, C. T. and T. W. Hughes. Phthalic Anhydride Plant Air Pollution Control. EPA-600/2-77-188. U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1977. 113p.

ABSTRACT: The report summarizes a technical and economic evaluation of add-on control systems and process modifications for reducing, by 99%, the emissions of phthalic and maleic anhydrides from the main process vent gas in phthalic anhydride manufacturing plants. A survey was made to identify present (1976) control practices and their control efficiencies in the phthalic anhydride industry. Based on theoretical and practical considerations, existing control technology alternatives were evaluated to determine whether they could be improved to obtain the desired control efficiency. Technical evaluation of these alternatives led to identification of candidate alternatives which apply to the manufacturing process, and which can achieve 99 percent overall removal efficiency for phthalic and maleic anhydrides. Design and operating parameters for achieving the desired control efficiency were also determined. Cost estimates and an energy utilization study were performed for the candidate alternatives. Demonstration programs are recommended for the most promising alternatives.

132. Control of Volatile Organic Emissions from Existing Stationary Sources. Volume 1: Control Methods for Surface-Coating Operations. EPA-450/2-76-028. U. S. Environmental Protection Agency, Research Triangle Park, NC, November 1976. 166p.

ABSTRACT: Available methods which can be used to control the emissions of organic vapors from surface coating operations are described. The methods consist of two types: (1) add-on control equipment, and (2) process and material changes. Available add-on equipment includes direct-flame incinerators, catalytic incinerators, and activated carbon adsorbers. Process and material changes which reduce or eliminate the use of organic solvents include (a) water-borne coatings, (b) high solids coatings, (c) powder coatings, (d) hot melt formulations, (e) electrostatic spraying, (f) electron beam curing, (g) ultraviolet curing. Graphs are given to determine the cost of incinerators at varying volumes and variation in inlet temperature, vapor concentration, degree of heat recovery, fuel costs, and hours of operation. Graphs are given to determine the cost of carbon adsorbers under varying volumes and vapor concentration. The available methods of measuring volatile organic emissions are discussed.

133. Allen, C. C., Jr. Environmental Assessment of Coke By-Product Recovery Plants. In: Proceedings of the First Symposium on Iron and Steel Pollution Abatement Technology, Chicago, IL, October 30-November 1, 1979. EPA-600/9-80-012. U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1980, pp. 75-88.

ABSTRACT: This paper identifies potential air pollution sources of environmental concern in coke by-product recovery plants. Data concerning the design and operation of existing plants and processes were collected. Since many process variations exist, a survey of the industry was carried out to determine the most common processes. Following this, the processes at a representative plant were sampled, using EPA's Industrial Environmental Research Laboratory RTP Level 1 protocol. Air pollutants of concern included benzene, cyanide, and polynuclear aromatic hydrocarbons. The air was sampled at suspected pollution sources, primarily storage tanks. The largest emission source was the final cooler tower where concentrations of aromatics at >50 g/Mg coke and cyanide at 278 g/Mg coke were found.

134. Kemner, W. F. and S. A. Tomes. Coke Battery Environmental Control Cost- Effectiveness. In: Proceedings of the First Symposium on Iron and Steel Pollution Abatement Technology, Chicago, Illinois, October 30 - November 1, 1979. EPA-600/9-80-012. U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1980. pp. 143-163.

ABSTRACT: A computerized optimization model has been developed to examine the cost-effectiveness of alternative emission control strategies for coke plants. The model calculates the lowest cost mix of controls to meet a given overall level of emissions for a given air pollutant, and also calculates the lowest overall emissions that can be achieved for a given cost. The data base is uncoupled from the model so that it can be updated as new or improved data become available. The present emission data base contains emissions factors for four air pollutants--particulate matter, benzene soluble organics, benzene, and benzo-a-pyrene--for 14 coke plant sources. The plant data base encompasses 216 batteries in 58 plants. The cost data base contains capital and annualized cost functions for 41 control techniques, but as many as eight control options can be accommodated for each source. The data base can be subdivided to enable examination of other factors, such as old versus new batteries or large versus small batteries. The optimization can be focused on either capital cost or annualized cost.

135. Buonicore, A. J. Environmental Assessment of Coke Quench Towers. In: Proceedings of the First Symposium on Iron and Steel Pollution Abatement Technology, Chicago, IL, October 30 - November 1, 1979. EPA-600/9-80-012. U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1980. pp. 112-125.

ABSTRACT: An environmental assessment of air emissions from both dry and wet quench towers was made based on data collected at U. S. Steel's Lorain plant, DOFASCO's No. 2 coke plant in Hamilton, Ontario, and at an Eschweiler Bergwerks-Verein (EBV) plant in Erin, W. Germany. Estimates of particulate emissions rates from the natural draft quench towers at Lorain and DOFASCO and from the pressure quench system at Erin are presented. Organic emission rates from the Lorain quench tower are reviewed and the environmental impact of dry quench towers is discussed.

136. Burklin, C. E., E. C. Cavanaugh, J. C. Dickerman, S. R. Fernandes, and G. C. Wilkins. Control of Hydrocarbons from Petroleum Liquids. EPA-600/2-75-042. U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1979. 231p.

ABSTRACT: The report is a state-of-the-art review of the availability and application of technology for the control of hydrocarbon emissions to the atmosphere from facilities for the production, refining, and marketing of liquid petroleum fuels. The review includes (1) identification of major hydrocarbon emission sources within the petroleum industry and the quantity of such source emissions, (2) review of existing hydrocarbon emission control technology and the extent of its application by the petroleum industry, and (3) identification of hydrocarbon emission sources within the petroleum industry for which control techniques are neither available nor widely applied.

137. Air Pollution Control Technology Applicable to 26 Source of Volatile Organic Compounds. U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1977. 75p.

ABSTRACT: This report reviews control technology for 26 principal sources of volatile organic compounds. Sources already investigated in control techniques guidelines documents are not included in this investigation. For each of the 26 sources, this report briefly describes applicable control technologies, costs, energy and environmental impacts, and factors which may limit applicability of the technologies. References are cited for each summary.

138. Kline, E. W. VOC Control Efforts by a Heavy Duty Truck Manufacturer. In: Third Conference on Advanced Pollution Control for the Metal Finishing Industry, Kissimmee, FL, April 14-16, 1980. EPA-600/2-81-028. U. S. Environmental Protection Agency, Cincinnati, OH, February 1981. pp. 102-103.

ABSTRACT: The author contends that there is no universal solution to VOC control unless a breakthrough in coating technology occurs. This paper concludes that a combination of improved transfer efficiency of coatings and materials substitution, when practical, appears to be the most favorable approach to VOC control. Incineration with heat recovery has application when an energy balance can be obtained. The use of carbon absorption or refrigeration principles have application when air volumes are low enough, or when there is a desire to recover lost product.

139. Health Assessment Document for Hexachlorocyclopentadiene. Review Draft. EPA-600/8-84-001A. U. S. Environmental Protection Agency, Cincinnati, OH, February 1984. 166p.

ABSTRACT: A computerized optimization model has been developed to examine the cost effectiveness of alternative emission control strategies for coke plants. The model calculates the lowest cost mix of controls to meet a given overall level of emissions for a given air pollutant, and also calculates the lowest overall emissions that can be achieved for a given cost. The data base is uncoupled from the model so that it can be updated as new or improved data become available. The present emission data base contains emission factors for four air pollutants--particulate matter, benzene soluble organics, benzene, and benzo-a-pyrene--for 14 coke plant sources. The plant data base encompasses 216 batteries in 58 plants. The cost data base contains capital and annualized cost functions for 41 control techniques, but as many as eight control options can be accommodated for each source. The data base can be subdivided to enable examination of other factors, such as old versus new batteries or large versus small batteries. The optimization can be focused on either capital cost or annualized cost.

140. Volatile Organic Compound (VOC) Species Data Manual. Second Edition. EPA-450/4-80-015. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1980. 465p.

ABSTRACT: This document contains tables of potential emissions of organic compounds for selecting source categories. The species profile table format has been organized to be particularly useful in preparation of emission inventory inputs to photochemical modeling. Accompanying each VOC profile table is a brief narrative that describes process, emissions, controls, and basis of source report and data quantification. The chemical classifications include paraffin, olefin, aromatic, carbonyl (aldehydes and ketones), methane, non-reactive other than methane, and miscellaneous. Data confidence levels for each profile table has been assigned. Reports, published data, and names and titles of personal contacts are referenced for each source category.

141. Rolke, R. W., R. D. Hawthorne, C. R. Garbett, E. R. Slater, T. T. Phillips, and G. D. Towell. Afterburner Systems Study. EPA-R2-72-062. U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1972. 512p.

ABSTRACT: The results are presented of a study of afterburner or fume incinerator technology for control of gaseous combustible emissions from stationary sources. The scope of the study included evaluation of current engineering technology, evaluation of existing afterburner systems, assessment of present practices and problems, determination of major sources and potential applications, and development of research recommendations. The main results of this study are presented as a handbook, allowing the potential user to be able to decide if his particular emission is amenable to afterburning and to obtain a rough estimate of cost and size of equipment needed. The user will also be made aware of potential problems and recommended design features. The user then would deal with the appropriate equipment supplier for details of equipment selection.

142. Safe, S., A. Parkinson, L. Robertson, T. Sawyer, and S. Bandiera. PCBs: Structure - Activity Relationships. EPA-600/D-83-096, U. S. Environmental Protection Agency, Duluth, MN, August 1983. 25p.

ABSTRACT: This report summarizes research on the chemical and toxicological characterization of PCBs. Results on the synthesis and characterization of all 209 PCBs and subsequent identification of individual PCB components in commercial mixtures and environmental samples are reported. This was essential for research relating the toxicity and biologic effects of commercial mixtures to chemical structure. The results of structure-activity research with the various congeners on several biological systems are also reported.

143. Kleeberg, C. F. and J. G. Wright. Control of Volatile Organic Emissions from Perchloroethylene Dry Cleaning Systems. EPA-450/2-78-050. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1978. 68p.

ABSTRACT: This report provides the necessary guidance for development of regulations limiting emissions of Volatile Organic Compounds (VOC) from perchloroethylene dry cleaning systems. Reasonably Available Control Technology (RACT) is defined and a cost analysis of RACT is included in order that cost effectiveness may be evaluated for these systems.

144. Zobel, K. J. and N. Efird. Control of Volatile Organic Emissions from Manufacture of Pneumatic Rubber Tires. EPA-450/2-78-030. U. S. Environmental Protection Agency. Research Triangle Park, NC, December 1978. 59p.

ABSTRACT: This document provides the necessary guidance for development of regulations to limit emissions of volatile organic compounds (VOC) for manufacture of pneumatic rubber tire operations. Emissions are characterized and reasonably available control technology (RACT) is defined for each of four major sources: green tire spraying, undertread cementing, tread-end cementing, and bead dipping. Information on cost of control and environmental impact is also included.

145. Serth, R. W. and T. W. Hughes. Source Assessment: Phthalic Anhydride (Air Emissions). EPA-600/2-76-032d. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1976. 157p.

ABSTRACT: The report gives results of an analysis of atmospheric (air) emissions from ortho-xylene- and napthalene-based phthalic anhydride manufacturing plants. Uncontrolled and controlled emission factors are given for each species emitted to the atmosphere from each source within a typical plant, based on the latest data available. Emissions data are used to calculate three factors designed to quantify the hazard potential of the emissions: (1) source severity (the ratio of the maximum mean ground-level concentration of a pollutant to the concentration which constitutes an incipient health hazard), (2) the industry contribution to total atmospheric emissions of criteria pollutants, and (3) the pollution exposed to high contaminant levels from a representative plant. Detailed process descriptions and flow sheets are presented for the BASF fixed-bed ortho-xylene process and the Badger-Sherwin-Williams fluid-bed naphthalene process. Present and future aspects of pollution control technology in the industry are discussed, including a number of possible process modifications. Economic and production trends in the phthalic anhydride industry and in each of the industries that are major consumers of phthalic anhydride are analyzed. Water-related emissions are to be discussed in a future, separate report.

146. Anderson, G. E. Human Exposure to Atmospheric Concentrations of Selected Chemicals. Volumes I and II. PB84-102540 (Vol. I). PB83-265249 (Vol. II). U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1983. 219p, 737p.

ABSTRACT: The two volumes summarize the results of a study conducted by the EPA's Office of Quality Planning and Standards to determine the human exposure to atmospheric concentrations of 40 selected chemicals. For each species, the following information was compiled: (1) emissions sources, including number, identification, and location of sources of each type;

(2) emission and rate modes; (3) physical and chemical data; and (4) concentration, exposure, and dosage patterns for source and source type, and total exposure and dosage.

147. Chandrasekhar, R. and E. Poulin. Control of Hydrocarbon Emissions from Cotton and Synthetic Textile Finishing Plants. EPA-600/2-83-041. U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1983. 151p.

ABSTRACT: This report describes the approach to, and conclusions resulting from, an evaluation of the applicability and economics of emissions control technologies for the abatement of volatile organic compounds emanating from cotton and synthetic textile finishing plants. A survey of the state-of-the-art and control technologies design and costing preceded the evaluation. The economic feasibility was determined in two steps: preliminary design, costing, and relative ranking of all identified applicable technologies; followed by more detailed design, costing, and evaluation of the most economically feasible technologies. A simple payback period approach was taken in the preliminary economic evaluation. Rates of return on capital investment were determined for the final detailed evaluation. Capital and operating costs are provided to allow interested parties to conduct in-house evaluations. Carbon bed adsorption with solvent recovery has been identified as the most viable of all technologies, and fluidized-bed carbon adsorption has the best potential to suit the variable operating conditions encountered in textile manufacturing. The potential cost benefits, even under far more stringent control requirements than existing regulations for the industry, appear attractive.

148. Pohl, J. H., R. Payne, and J. Lee. Evaluation of the Efficiency of Industrial Flares: Test Results. EPA-600/2-84-095. U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1984. 192p.

ABSTRACT: This report provides the results of Phases 3 and 4 of the following four-phase research program to quantify the emissions and efficiencies of industrial flares: Phase 1 - experimental design; Phase 2 - design of test facilities; Phase 3 - development of test facilities; Phase 4 - data collection and analysis. Measurements were made of the combustion efficiency of large pilot-scale flares. The flame structure and combustion efficiencies were correlated with operating conditions of the flare, size of the flare head, and properties of the flared gases. The combustion efficiency was correlated with the ratio of heating value of the gas flared to the heating value required to maintain a stable flame, and was independent of the flame head size. In turn, the heating value required to maintain a stable flame was correlated with the reciprocal of an estimated flame temperature based on properties of the flared gas. Other correlations for the length of the flame, entrainment into the flame, and liftoff distances were developed using combinations of the Richardson Number, jet theory, and the properties of the flared gas.

149. Joseph, D., J. Lee, C. McKinnon, R. Payne, and J. Pohl. Evaluation of the Efficiency of Industrial Flares: Background--Experimental Design--Facility. EPA-600/2-83-070. U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1983. 284p.

ABSTRACT: This report provides the results of Phases 1 and 2 of the following four-phase research program to quantify the emissions and efficiencies of industrial flares: Phase 1 - experimental design; Phase 2 - design of test facilities; Phase 3 - development of test facilities; Phase 4 - data collection and analyses. This report summarizes the technical literature on the use of industrial flares and reviews available emission estimates. Technical critiques of past flame efficiency studies are provided. Mathematical models of flame behavior are explored and recommendations for flare flame models are made. The parameters affecting flare efficiency are evaluated and a detailed experimental test plan is developed. The design of a flare test facility is provided, including details on the flare tips, fuel and steam supplies, flow control and measurement, emissions sampling and analysis, and data acquisition and processing.

150. McDaniel, M, Flare Efficiency Study. EPA-600/2-83-052. U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1983. 142p.

ABSTRACT: The report gives results of a full-scale experimental study to determine the efficiencies of flare burners for disposing of hydrocarbon emissions from refinery and petrochemical processes. With the primary objectives of determining the combustion efficiency and hydrocarbon destruction efficiency for both air- and steam-assisted flares under a wide range of operating conditions, it provides a data base for defining the air quality impact of flaring. Test results indicate that flaring is generally an efficient hydrocarbon disposal method for the conditions evaluated. Test methodology involved a special 27-foot sample probe suspended by a crane over the flare flame. The sample extracted by the probe was analyzed by continuous emission monitors to determine concentrations of carbon dioxide, carbon monoxide, total hydrocarbons, sulfur dioxide, oxides of nitrogen, and oxygen. In addition, the probe tip temperature, ambient air temperature, and wind speed and direction were measured. Integrated samples of the relief gas were collected for hydrocarbon species analysis by gas chromatograph. Particulate matter samples were collected during the smoking flare tests. When flares were operated under conditions representing good industrial operating practice, combustion efficiencies at the sampling probe were greater than 98 percent. Combustion efficiencies declined under conditions of excessive steam (steam quenching) and high exit velocities of low-Btu content gases.

151. Jennings, M. S., N. E. Krohn, and R. S. Berry. Control of Industrial VOC Emissions by Catalytic Incineration. Volume 1: Assessment of Catalytic Incineration and Competing Controls. EPA Contract 68-02-3171, Tasks 39 and 50. Radian Corporation, Research Triangle Park, NC, April 26, 1984.

ABSTRACT: This report provides the results of Phase 1 of the following two-phase study designed to assess the performance, suitability, and costs of various VOC control technologies: Phase 1 - overview and assessment of catalytic incineration and alternate VOC control technologies; Phase 2 - testing program. This phase of the study summarizes the available literature on the use and cost of using catalytic incineration for VOC control. The report reviews current and developing technology, assesses the overall performance of catalytic incinerators, and reviews current applications. It compares catalytic incineration with other competing VOC controls. The report also examines available methods for emission testing of catalytic incinerators and evaluates the need for additional performance test data.

152. Radian Corporation. Performance of Catalytic Incinerators at Industrial Sites. EPA Contract 68-02-3171, Task 50. Durham, NC, June 15, 1983. 83p.

ABSTRACT: This report provides the results of Phase 2 of the following two-phase study designed to assess the performance, suitability, and costs of various VOC control technologies: Phase 1 - overview and assessment of catalytic incineration and alternative VOC control technologies; Phase 2 - testing program. This phase of the study describes tests of eight catalytic incinerators at six industrial sites between November 1982 and March 1983. Incinerators at can coating, coil coating, magnet wire, and graphic arts printing plants were tested. Incinerator performance was characterized in terms of destruction efficiency, outlet solvent concentration, and energy usage. Inlet and outlet solvent concentrations were monitored with hydrocarbon analyzers during a nominal 1-week test period at each site. Incinerator design and operating data, such as operating temperature, solvent type, catalyst volume and catalyst age, were collected on each incinerator to document the operating conditions during the test.

153. U. S. Environmental Protection Agency. Perchloroethylene Dry Cleaners - Background Information for Proposed Standards. EPA-450/3-79-029a. Research Triangle Park, NC, August 1980. 165p.

ABSTRACT: Standards of Performance for the control of emissions from perchloroethylene dry cleaning facilities are being proposed under the authority of Section 111 of the Clean Air Act. Perchloroethylene dry cleaners include the following categories: coin-operated, commercial, and industrial. These standards apply to new, modified, or reconstructed facilities, the construction or modification of which began on or after the date of proposal. This draft document contains background information, environmental and economic impact assessments, and the rationale for the standards as proposed under 40 CFR Part 60, Subpart OO.

154. U. S. Environmental Protection Agency. Inorganic Arsenic Emissions from Gloss Manufacturing Plants - Background Information for Proposed Standards. EPA 450/3-83-011a. Research Triangle Park, NC, April 1983. 183p.

ABSTRACT: A national emission standard for glass manufacturing plants is being proposed under authority of Section 112 of the Clean Air Act. The purpose of the proposed standard is to minimize glass manufacturing furnace arsenic emissions to the level which, in the judgment of the Administrator of the U. S. Environmental Protection Agency, provides an ample margin of safety to protect the public health. The standard will have the effect of reducing uncontrolled emissions of arsenic from these furnaces by about 90 percent. Environmental impact and economic impact statements quantifying the impacts of the propsed standard and alternative control options are included in the document.

155. Schwitzgebel, K., G. S. Gunn, and M. A. Capalongan. Fugitive Emissions at a Secondary Lead Smelter. EPA Contact No. 68-02-3513. Radian Corporation, Austin, TX, December 1981.

ABSTRACT: This report describes an EPA-funded project to provide support to the Commonwealth of Pennsylvania, Department of Environmental Resources, in development of Pennsylvania's State Implementation Plan for lead. This report describes the smelter in terms of the plant environment, process description and emission sources; it provides the results of the sampling and analysis, outlining the approach and the analytical procedures; and it evaluates the data necessary to quantify fugitive lead emissions.

156. Hartman, M. and C. Stackhouse. Source Sampling Report for General Battery Corporation: Measurement of Arsenic/Lead/Cadmium, Unit #1, Secondary Lead Smelter Process, Reading, Pennsylvania. EMB Report 83-SLD-2. U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1983.

ABSTRACT: This report describes testing at the General Battery plant at Reading, Pennsylvania during the period June 19-June 23, 1983. Sampling was conducted at the inlet and outlet location around the fabric filter baghouse and the wet scrubber systems. The primary sampling method was EPA Draft Method 108 with EPA Reference Methods 1, 2, 3, and 6 used for flow and gas constituents. Special Method 108 runs were performed with the train maintained at process temperatures.

6.2 HAP DATA BASE CLASSIFICATION

GROUP 1: PHYSICAL/CHEMICAL PROPERTIES

7. Burce, W. D., J. W. Blackburn, V. Kalcevic, S. W. Dylewski, and R. E. White. Organic Chemical Manufacturing. Volume 6: Selected Processes. EPA-450/3-80-028a. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 404p.

8. Hobbs, F. D., C. W. Stuewe, S. W. Dylewski, D. M. Pitts, and C. A. Peterson. Organic Chemical Manufacturing. Volume 7: Selected Processes. EPA-450/3-80-28b. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 398p.

9. Key, J. A., C. W. Stuewe, R. L. Standifer, F. D. Hobbs, and D. M. Pitts. Organic Chemical Manufacturing. Volume 8: Selected Processes. EPA-450/3-80-28c. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 363p.

10. Lovell, R. J., J. A. Key, R. L. Standifer, V. Kalcevic, and J. F. Lawson. Organic Chemical Manufacturing. Volume 9: Selected Processes. EPA-450/3-80-28d. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 545p.

11. Peterson, C. A., J. A. Key, F. D. Hobbs, J. W. Blackburn, and H. S. Basdekis. Organic Chemical Manufacturing. Volume 10: Selected Processes. EPA-450/3-80-28e. U. S. Environmental Protection Agency, Research Triangle Park, NC, 1980. 578p.

31. Horn, D. A., D. R. Tierney, and T. W. Hughes. Source Assessment: Polychloroprene. State of the Art. EPA-600/2-77-107o. U. S. Environmental Protection Agency, Research Triangle Park, NC., 1977, 97p.

32. Health Assessment Document for Toluene. EPA-600/8-82-008f. U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1983. 427p.

33. Anderson, L. D., S. Bayard, I. W. F. Davidson, J. R. Fowle, III, H. J. Gibb, M. Greenberg, and J. C. Parker. Health Assessment Document for Trichloroethylene. External Review Draft. EPA-600/8-82-006b. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1983. 397p.

34. Cleland, J. G., G. L. Kingsbury, R. C. Sims, and J. B. White. Multimedia Environmental Goals for Environmental Assessment, Volumes 1 and 2. EPA-600/7-77-136a and EPA-600/7-77-136b. U. S. Environmental Protection Agency, Research Triangle Park, NC, November 1977. 366p, 451p.

39. Fuller, B., J. Hushon, M. Kornreich, R. Ouellette, and L. Thomas. Preliminary Scoring of Selected Organic Air Pollutants. EPA-450-/3-77-008a. U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1976. 114p.

40. Dorigan, J., B. Fuller, and R. Duffy. Preliminary Scoring of Selected Organic Air Pollutants. Appendix I: Chemistry, Production and Toxicity of Chemicals A through C. EPA-450/3-77-008b. U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1976. 330p.

41. Dorigan, J., B. Fuller, and R. Duffy. Preliminary Scoring of Selected Organic Air Pollutants. Appendix II: Chemistry, Production, and Toxicity of Chemicals D through E. EPA-450/3-77-008c. U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1976. 336p.

42. Dorigan, J., B. Fuller, and R. Duffy. Preliminary Scoring of Selected Organic Air Pollutants. Appendix III. Chemistry, Production, and Toxicity of Chemicals F through N. EPA-450/3-77-008d. U. S. Environmental Protection Agency, Research Triangle, NC, October 1976. 312p.

43. Dorigan, J., B. Fuller, and R. Duffy. Preliminary Scoring of Selected Organic Air Pollutants. Appendix IV. Chemistry, Production, and Toxicity of Chemicals F through N. EPA-450/3-77-008e. U. S. Environmental Protection Agency, Research Triangle, NC, October 1976. 333p.

45. Chemical Hazard Information Files (CHIPs). EPA-560/11-80-011. U. S. Environmental Protection Agency, Washington, DC, April 1980. 296p.

52. Hoff, M. C. Toluene. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 23. John Wiley & Sons, Inc., New York, NY, 1982. pp. 246-273.

53. Johnson, P. R. Chloroprene. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 5. John Wiley & Sons, Inc., New York, NY, 1982. pp. 773-785.

54. Gelfand, S. Chlorocarbons, Chlorohydrocarbons (Benzyl): Benzyl Chloride, Benzal Chloride, Benzotrichloride. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 5. John Wiley & Sons, Inc., New York, NY, 1982. pp. 828-838.

55. Hess, L. G., A. N. Kurtz, and D. B. Stanton. Acrolein and Derivatives. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 1. John Wiley & Sons, Inc., New York, NY, 1982. pp. 277-297.

74. Radian Corporation. Locating and Estimating Air Emissions from Sources of Nickel. Draft. EPA Contract No. 68-02-3513, Work Assignment No. 22. Durham, NC, November 1983. 166p.

75. Radian Corporation. Estimates of Population Exposure to Ambient Chromium Emissions. Draft. EPA Contract No. 68-02-3818, Work Assignment No. 2. Durham, NC, August 1983. 184p.

77. GCA Corporation. Survey of Cadmium Emission Sources. EPA-450/3-81-013. U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1981. 157p.

78. Hardy, E. R. Phosgene. In: Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. Volume 17. John Wiley & Sons, New York, NY, 1982, pp. 416-425.

81. Serth, R. W., D. R. Tierney, and T. W. Hughes. Source Assessment: Acrylic Acid Manufacture; State of the Art. EPA-600/2-78-004W. U. S. Environmental Protection Agency, Cincinnati, OH, August 1978. 83p.

118. Sittig, M. Handbook of Toxic and Hazardous Chemicals. Noyes Data Corporation, Park Ridge, NJ, 1981. 729p.

139. Health Assessment Document for Hexachlorocyclopentadiene. Review Draft. EPA-600/8-84-001A. U. S. Environmental Protection Agency, Cincinnati, OH, February 1984. 166p.

142. Safe, S., A. Parkinson, L. Robertson, T. Sawyer, and S. Bandiera. PCBs: Structure - Activity Relationships. EPA-600/D-83-096, U. S. Environmental Protection Agency, Duluth, MN, August 1983. 25p.

146. Anderson, G. E. Human Exposure to Atmospheric Concentrations of Selected Chemicals. Volumes I and II. PB84-102540 (Vol. I). PB83-265249 (Vol. II). U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1983. 219p, 737p.

HAP DATA BASE CLASSIFICATION

GROUP 2: MANUFACTURING INFORMATION[a]

2. White, R. E. Organic Chemical Manufacturing. Volume 1: Program Report. EPA-450/3-80-023. U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1980. 92p.

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HAP DATA BASE CLASSIFICATION

GROUP 6: GENERAL[e]

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HAP DATA BASE CLASSIFICATION

SUBJECT GROUP DESCRIPTIONS

[a]Manufacturing Information -- This group includes references containing manufacturing data concerning producers, production rate, and plant location. Also included are the references that report HAP monitoring data at different locations.

[b]Reaction/Process/Industry Descriptions -- This group includes references that contain information on reactions and/or processes employed in production of HAPs. References that contain descriptions of industries emitting HAPs are also included in this group.

[c]Emission Sources/Rates/Factors -- This group contains references pertaining to emissions from production and/or consumption, storage and handling, as well as fugitive and secondary emissions. References with information on actual and/or estimated emissions rates and factors are included in this group.

[d]Emission Controls -- In this group, the references relating to actual plant control practices and/or applicable control techniques for HAPs are included. This group also contains the references that have general information on control technology.

[e]General -- This group includes general references such as published literature searches, Chemical Activities Status Report, etc.

APPENDIX A

PHYSICAL AND CHEMICAL PROPERTY DATA

TABLE A-1. PHYSICAL PROPERTIES[a]

Name	Molecular Formula	Molecular Weight	Physical State	Vapor Pressure	Vapor Specific Gravity	Boiling Point	Melting Point	Log Partition Coefficient (Octanol/H_2O)	Liquid Specific Gravity	Solubility
Acetaldehyde	C_2H_4O	44.05	L	923mm at 25°C	1.52	20.8°C	-121°C	0.43	0.7834 at 18°C/4°C	Infinite
Acetic acid	C_2HO_2	60.05	L	11.4mm at 20°C	2.07	117.9°C	16.6°C	-0.31	1.0492 at 20°C/4°C	Infinite
Acetic anhydride	$C_4H_6O_3$	102.09	L	5.09mm at 25°C	3.50	139.55°C	-73.1°C		1.082 at 20°C/4°C	Very soluble
Acetone	C_3H_6O	58.08	L	400mm at 39.5°C	2.00	56.2°C	-95.35°C	0.55	0.7972 at 15°C/4°C	Infinite
Acrolein	C_3H_4O	56.06	L	288.2mm at 25°C	1.94	52.5°C	-86.95°C		0.841 at 20°C/4°C	Very soluble
Acrylic acid	$C_3H_4O_2$	72.06	L	4.61mm at 25°C	2.45	14.1°C	13°C	0.43	1.0511 at 20°C/4°C	Infinite
Acrylonitrile	C_3H_3N	53.00	L	113.8mm at 25°C	1.83	77.5°C	-83 to -84°C	-0.92	0.8060 at 20°C/4°C	Soluble
Adipic acid	$C_6H_{10}O_4$	146.14	S	1mm at 159.5°C	5.04	337.5°C	153°C	-0.14	1.360 at 25°C/4°C	Slightly soluble
Allyl alcohol	C_3H_6O	58.08	L	25.6mm at 25°C	2.00	97°C	-129°C	0.13	0.8540 at 20°C/4°C	Infinite
Allyl chloride	C_3H_5Cl	76.58	L	359mm at 25°C	2.64	44.6°C	-134.5°C		0.938 at 20°C/4°C	Soluble
Aniline	C_6H_7N	93.12	L	0.67mm at 25°C	3.22	184°C	-6.3°C	1.24	1.0217 at 20°C/4°C	Soluble
Benzene	C_6H_6	78.11	L	95.9mm at 25°C	2.77	80.1°C	5.5°C	2.28	0.8787 at 20°C/4°C	Slightly soluble
Benzo(a)pyrene[b]	$C_{20}H_{12}$	252.30		10mm at 310-312°C		496-510°C	179°C			Insoluble
Benzyl chloride	C_7H_7Cl	126.50	L	1.4mm at 25°C	4.36	179°C	-39°C		1.1026 at 18°C/4°C	Insoluble
1,3 Butadiene	C_4H_6	54.09	G	1690mm at 25°C	1.87	-4.5°C	-109.91°C		0.621 at 20°C/4°C	Insoluble
Cadmium	Refer to Table A-2									
Caprolactam	$C_6H_{11}NO$	113.16	S	6mm at 120°C		139°C at 12mm	69 to 71°C			Soluble
Carbon tetrachloride	CCl_4	153.82	L	115.2mm at 25°C	5.32	76.54°C	-22.99°C	2.64	1.5940 at 20°C/4°C	Insoluble
Chlorobenzene	C_6H_5Cl	112.56	L	12.14mm at 25°C	3.88	131.7°C	-45.6°C	2.84	1.1058 at 20°C/4°C	Insoluble
Chlorodifluoromethane	$CHClF_2$	86.48	G	2210.6mm at 25°C		-40.8°C	-160°C		1.194 at 25°C/4°C	Partly soluble
Chloroform	$CHCl_3$	119.39	L	200mm at 25.9°C	4.12	61.26°C	-63.5°C	1.17	1.4985 at 15°C	Soluble
Chloroprene	C_4H_5Cl	88.54	L	215.4mm at 25°C		59.4°C			0.9583 at 20°C/4°C	Slightly soluble
Chromium	Refer to Table A-2									
m-Cresol	C_7H_8O	108.1	L	1mm at 52.0°C	3.72	202.8°C	12°C	2.37	1.034 at 20°C/4°C	Slightly soluble
o-Cresol	C_7H_8O	108.1	S	1mm at 38.2°C	3.72	190.8°C	30.9°C	3.40	1.047 at 20°C/4°C	Soluble
p-Cresol	C_7H_8O	108.1	S	1mm at 53°C	3.72	201.8°C	35.26°C	2.35	1.0341 at 20°C/4°C	Slightly soluble
Cumene	C_9H_{11}	120.21	L	6.56mm at 25°C	4.10	152°C	-96°C		0.864 at 20°C/4°C	Insoluble
Cyclohexane	C_6H_{12}	54.16	L	98.14mm at 25°C	2.90	80.7°C	6.3°C		0.7786 at 20°C/4°C	Insoluble
Cyclohexanol	$C_6H_{12}O$	100.17	L	1.7mm at 25°C	3.45	161.5°C	23°C		0.9449 at 25°C/4°C	Soluble

TABLE A-1. PHYSICAL PROPERTIES[a] (CONTINUED)

Name	Molecular Formula	Molecular Weight	Physical State	Vapor Pressure	Vapor Specific Gravity	Boiling Point (°C)	Melting Point (°C)	Log Partition Coefficient (Octanol/H_2O)	Liquid Specific Gravity	Solubility
Cyclohexanone	$C_6H_{10}O$	98.14	L	4.[illegible]mm at 25°C	3.4	155.6°C	-47°C	0.01	0.9478 at 20°C/4°C	Soluble
Dichlorodifluro-methane	CCl_2F_2	120.92	G	5[illegible]3mm at 25°C		-29.8°C	-158°C		1.311 at 25°C/4°C	Soluble
Dichlorotetra-fluoroethane	$C_2Cl_4F_4$	170.94	G	1680.77mm at 25°C		3.6°C	-94°C		1.455 at 25°C/4°C	Insoluble
Diethanolamine	$C_4H_{11}NO_2$	105.14	L	5mm at 25°C	3.65	269.1°C	28°C	-2.02	1.092 at 20°C/4°C	Infinite
Dimethyl nitrosamine	$C_2H_6N_2O$	74.08	L			154°C			1.0059 at 20°C/4°C	Soluble
Dimethyl terephthalate	$C_{10}H_{10}O_4$	194.19	S	1mm at 100°C		Sublimes	141.0 to 141.8°C		1.194 at 20°C/4°C	Slightly soluble
Epichlorohydrin	C_3H_5ClO	92.53	L	16.8mm at 25°C	3.29	117.9°C	-48°C		1.1801 at 20°C/4°C	Slightly soluble
Ethyl acrylate	$C_5H_8O_2$	100.00	L		3.50		43°C at 102.8mm		0.9234 at 20°C/4°C	Soluble
Ethylbenzene	C_8H_{10}	106.17	L	9.63mm at 25°C	3.66	136.2°C	-94.97°C	3.15	0.8670 at 20°C/4°C	Insoluble
Ethylene	C_2H_4	28.06	G	34200mm at 0°C	0.98	-103.9°C	-169°C		0.9927 at 20°C/4°C	Insoluble
Ethylene dichloride	$C_2H_4Cl_2$	99.00	L	84.42mm at 25°C	3.35	83.5°C	-35.5°C		1.257 at 20°C/4°C	Slightly soluble
Ethylene glycol	$C_2H_6O_2$	62.10	L	0.05mm at 20°C	2.14	198°C	-11.5°C	-1.88	1.1088 at 20°C/4°C	Infinite
Ethylene oxide	C_2H_4O	44.05	G	1475mm at 25°C	1.52	13.5°C	-111.3°C		0.8711 at 20°C/20°C	Soluble
Formaldehyde	CH_2O	30.03	G	1946.67mm at 25°C		-21°C	-92°C	-0.96	0.815 at 20°C/4°C	Soluble
Formic acid	CH_2O_2	46.30	L	42.38mm at 25°C	1.59	100.8°C	8.3°C	-0.73	1.2201 at 20°C/4°C	Soluble
Hexachloro-cyclopentadiene	C_5Cl_6	272.79	L	0.08mm at 25°C	9.40	239°C at 753mm	-9.6°C	5.04	1.7019 at 15°C	Slightly soluble
Maleic anhydride	$C_4H_2O_3$	98.06	S	1mm at 44°C	3.40	197 to 199°C	60°C		1.48 at 20°C/4°C	Reacts with H_2O, soluble
Manganese	Refer to Table A-2									
Methanol	CH_4O	32.04	L	127.9mm at 25°C	1.11	64.8°C	-93.9°C		0.7913 at 20°C/4°C	Infinite
Methyl chloride	CH_3Cl	50.49	G	2.83atm at 25°C	1.78	-24.2°C	-97.73°C		0.9159 at 20°C/4°C	Soluble
Methyl chloroform	$C_2H_3Cl_3$	133.41	L	130.86mm at 25°C	4.55	74.1°C	-30.41°C		1.3390 at 20°C/4°C	Insoluble
Methyl ethyl ketone	C_4H_8O	72.12	L	96.4mm at 25°C	2.41	79.6	-86.35°C	0.29	0.8054 at 20°C/4°C	Very soluble

TABLE A-1. PHYSICAL PROPERTIES[a] (CONTINUED)

Name	Molecular Formula	Molecular Weight	Physical State	Vapor Pressure	Vapor Specific Gravity	Boiling Point (°C)	Melting Point (°C)	Log Partition Coefficient (Octanol/H_2O)	Liquid Specific Gravity	Solubility
Methyl methacrylate	$C_5H_8O_2$	100.13	L	40mm at 25.5°C	3.45	100 to 101°C	-48°C		0.9440 at 20°C/4°C	Slightly soluble
Methylene chloride	CH_2Cl_2	84.93	L	435.8mm at 25°C	2.93	40°C	-95.1°C		1.3266 at 20°C/4°C	Slightly soluble
Nickel	Refer to Table A-2									
Nitrobenzene	$C_6H_5NO_2$	123.06	S/oily L	0.284mm at 25°C	4.25	210.8°C	5.7°C	1.88	1.2037 at 20°C/4°C	Slightly soluble
Nitrosomorpholine[d]	C_4H_9NO	87.12	L	10mm at 23°C	3.00	128.3°C	-4.75°C	-1.08	1.00 at 20°C/4°C	Infinite
Perchloroethylene	C_2Cl_4	165.82	L	18.47mm at 25°C	5.83	121.20°C	-19°C		1.6227 at 20°C/4°C	Insoluble
Phenol	C_6H_6O	94.11	S	0.53mm at 25°C	3.24	181.9°C	4.25-43°C		1.0576 at 20°C/4°C	Soluble
Phosgene	CCl_2O	98.92	G/ volatile L	1428mm at 25°C	3.40	7.56°C	-118°C		1.392 at 19°C/4°C	Decomposes in H_2O
Phthalic anhydride	$C_8H_4O_3$	148.12	S	1mm at 96.5°C	5.10	295.1°C	131.61°C		1.527 at 4°C	Slightly soluble
Polychlorinated biphenyls[e]	$C_{12}Cl_n$[f]		L/S			278 to 475°C				
Arachlor 1254			L/S	1mm at 25°C		365 to 390°C			1.495 to 1.505 at 65°C/15.5°C	Slightly soluble
Propylene oxide	C_3H_6O	58.08	L	596mm at 25°C	2.00	33.9°C	-104.4°C		0.8394 at 20°C/4°C	Soluble
Styrene	C_8H_8	104.14	L	6.05mm at 25°C		146°C	-30.63°C		0.904.5 at 25°C/25°C	Insoluble
Terephthalic acid	$C_8H_6O_4$	166.14	S	negligible		Sublimes	Sublimes without melting		1.51	Insoluble
Toluene	C_7H_8	92.15	L	28.4mm at 25°C	3.14	110.6°C	-95°C		0.8669 at 20°C/4°C	Insoluble
Toluene Diisocyanate	$C_9H_6N_2O_2$	174.16	L	<0.01mm at 20°C	6.00	238.3°C	19.5 to 21.5°C		1.22 at 20°C/4°C	Reacts with H_2O
Trichloroethylene	C_2HCl_3	131.39	L	77.5mm at 25°C	4.53	87°C	-73°C		1.4642 at 20°C/4°C	Slightly soluble
Trichlorofluoromethane	CCl_3F	137.38	L	717.5mm at 25°C	24.1°C		-111°C		1.494 at 17.2°C/4°C	Slightly soluble
Trichlorotrifluoroethane	$C_2Cl_3F_3$	187.38	L	337.72mm at 25°C	6.47	47.7°C	-36.4°C		1.5635 at 25°C/4°C	Insoluble
Vinyl acetate	$C_4H_6O_2$	86.09	L	107.5mm at 25°C	3.00	72.2 to 72.3°C	-93.2°C		0.9317 at 20°C/4°C	Insoluble (soluble in hot H_2O)

TABLE A-1. PHYSICAL PROPERTIES[a] (CONCLUDED)

Name	Molecular Formula	Molecular Weight	Physical State	Vapor Pressure	Vapor Specific Gravity	Boiling Point (°C)	Melting Point (°C)	Log Partition Coefficient (Octanol/H_2O)	Liquid Specific Gravity	Solubility
Vinyl chloride	C_2H_3Cl	62.50	L/G	2660mm at 25°C	2.15	-13.4°C	-153.8°C		0.9195 at 15°C/4°C	Slightly soluble
Vinylidene chloride	$C_2H_2Cl_2$	97.00	L	617.14 at 25°C		37°C	-122.53°C		1.213 at 20°C/4°C	Insoluble
m-Xylene	C_8H_{10}	106.20	L	8.56mm at 25°C	3.66	139°C	-47.4°C		0.864 at 20°C/4°C	Insoluble
o-Xylene	C_8H_{10}	106.20	L	10mm at 32.1°C	3.66	144.4°C	-25°C		0.880 at 20°C/4°C	Insoluble
p-Xylene	C_8H_{10}	106.20	L	10mm at 25°C	3.66	138.5°C	13.2°C		0.8611 at 20°C/4°C	Insoluble
Zinc	Refer to Table A-2									

[a] References 40-43 unless otherwise noted

[b] Benzo(a)pyrene is a major constituent of polycyclic organic matter (POM) emitted from combustion sources; Reference 34.

[c] Reference 9.

[d] Reference 1.

[e] Reference 34.

[f] n = 1 to 10; the density, boiling point, and melting point increase with chlorine content.

TABLE A-2. PHYSICAL AND CHEMICAL PROPERTIES[a]

	Atomic Number	Group	Atomic Weight	Melting Point	Boiling Point	Density	Vapor Pressure	Valency	Solubility in Water
Cadmium	48	2B	112.4	320.9°C	765°C	8.64 g/cm^3	1mm at 394°C	2	Insoluble
Chromium	24	6	51.996	1890°C	2642°C	7.20 g/cm^3		3,2,6	
Copper	29	1B	63.546	1083±0.1°C	2336°C	8.92 g/cm^3	1mm at 1628°C	1,2	Insoluble
Manganese	25	7B	54.938	1244±3°C	1962°C		1mm at 1292°C	2,3,4,6,7	Decomposes in water
Nickel	28	8	58.71	1453°C	2732°C	8.90 g/cm^3	1mm at 1810°C	-1,0,1,2,3,4	Insoluble
Zinc	30	2B	65.38	419.5°C	908°C	7.14 g/cm^3	1mm at 487°C	2	Insoluble

[a] Reference 34.

APPENDIX B

CONTROL TECHNOLOGY INFORMATION SUMMARY FOR HAP's

ACETALDEHYDE[10]

Source of emissions: Manufacturing of acetaldehyde from ethylene by two-step air oxidation

Emissions: Acetaldehyde, ethyl chloride, methyl chloride, chloroform, ethylene, methylene chloride

Control Device/Practice	Comments
Absorber	Absorbers (water scrubbers) are used for product recovery. They are considered as integral components of process equipment.
Flare	Flares are used to control emissions from the absorbers. The composition of a waste stream fed to a process flare is shown in Table B-1.
Recycle	Emissions from process vents, product storage tanks, and product tank car loading systems are controlled by recycling to process.

TABLE B-1. COMPOSITION OF WASTE STREAM FED TO A FLARE[a]

Compound	Composition (Wt. %)
C_2H_4	0.9
CH_3Cl	1.9
C_2H_5Cl	2.1
CH_2Cl_2	0.3
$CHCl_3$	0.7
N_2	37.5
O_2	0.9
CO_2	41.9
CH_4	11.9
C_2H_6	2.9

[a] Celanese Chemical Plant, Reference 10.

ACETIC ACID[11, 125]

Source of emissions: Manufacture of acetic acid by (a) methanol carbonylation, (b) n-butane oxidation, and (c) acetaldehyde oxidation

Emissions: Acetic acid, methanol, formic acid, ethyl acetate, methyl ethyl ketone, acetaldehyde, methyl acetate, ethanol, butanol, n-propyl acetate, acetone, methyl formate

Control Device/Practice	Comments	Control Efficiency (VOC)
Source (a)		
Flare	The process emissions from the scrubber are sent to a flare.	98.5%[a]
Recycle	Reactor off-gas from the high-pressure absorber is sent back to the process.	
Scrubber	A series of scrubbers are used for recovery of organics from the distillation column vents.	
	The final scrubber uses chilled methanol as the scrubbing liquid and acts as an emission control device.	80%
Source (b)		
Condenser	A refrigerated condenser is used to control the VOC in the vent gases from the separator condenser. Composition data are reported in Table B-2.	68%
	Refrigerated condensers are also used on purification vents.	60%
Flare	A flare is used to control emissions from the stripper condenser. Composition data are reported in Table B-3.	95%

CONTINUED

ACETIC ACID[11, 125] (CONTINUED)

Control Device/Practice	Comments	Control Efficiency (VOC)
Source (c)		
Scrubber	Gases from distillation column condensers and accumulators are sent to a unit vent scrubber. Composition data are given in Table B-4.	
	Scrubber on the reactor vent is used for recovering product and raw materials.	
	A scrubber employs water and acetic acid to remove VOC from the reactor off-gas.	99%
Condenser	A water-cooled vent condenser is used as a control device on one column.	99%[b]

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[a] Vendor estimate for acetic acid removal.
[b] n-propyl acetate removal efficiency.

TABLE B-2. COMPOSITION DATA FOR WASTE STREAM TRANSFERRED TO A REFRIGERATED CONDENSER[a]

Component	Composition (Wt. %)
Butane	6.5
Ethane	0.8
Other organics	-
Total VOC	7.3
Methane	4.6
Carbon dioxide	56
Carbon monoxide	9
Nitrogen	8.1
Argon	15

[a] Union Carbide Corp., South Charleston, W. VA. Reference 11.

TABLE B-3. COMPOSITION DATA FOR WASTE STREAM TRANSFERRED TO A FLARE[a]

Component	Composition (Wt %)
Butane	11
Ethane	1
Other organics	4
Total VOC	16
Methane	1
Carbon dioxide	80
Carbon monoxide	1
Nitrogen	1
Argon	1

[a] Union Carbide Corp., South Charleston, W. VA. Reference 11.

TABLE B-4. COMPOSITION DATA FOR WASTE STREAM SENT TO UNIT VENT SCRUBBERS[a]

Compound	Composition (Wt. %)
N_2	96.3
H_2O	3.2
C_2H_4O	0.5

[a] Celanese, Clear Lake, Texas. Reference 11.

ACETIC ANHYDRIDE[11]

Source of emissions: Manufacture of acetic anhydride by pyrolysis of acetic acid

Emissions: Ethylene, benzene[a], propadiene, acetic, acetic anhydride, acetone

Control Device/Practice	Comments	Control Efficiency (VOC)
Fuel gas	Reactor byproduct gases are collected and burned as supplemental fuel in the pyrolysis furnaces. A typical analysis of the gas sent to the pyrolysis furnace is given in Table B-5.	100%[b] (organics)
Thermal incinerator	The emissions from the vacuum ejector system or gas scrubbers are controlled by incinerating in off-gas burners. Heat is recovered from the incinerator flue gases by a waste heat boiler. Composition data from one plant is shown in Table B-6.	

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[a] Benzene emissions are present only if the pyrolysis process with benzene quench used.

[b] Organic removal efficiency.

TABLE B-5. COMPOSITION DATA FOR WASTE STREAM TRANSFERRED TO PYROLYSIS FURNACE[a]

Compound	"Decomp Gas" Feed to Furnace	Furnace Stack	
	Composition (Wt. %)	(ppm)	(lb/hr)
Methane	2.2	6.9	0.053
VOC[b]	29.7	1.1	0.007
CO	35.2	1.6	0.021
CO_2	26.0		
Benzene	4.4		
SO_2		0.0	
NO_x		91.5	2.009
Others	6.9	61.53	
Flowrate = 935 lb/hr			

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[a] Reference 11.

[b] Volatile organic compounds other than methane.

TABLE B-6. COMPOSITION DATA FOR WASTE STREAM SENT TO OFF-GAS BURNER[a]

Compound	Composition (Mol %)
Allene and/or methyl acetylene	10.1
Butadiene	0.9
Carbon dioxide	22.8
Carbon monoxide	46.6
Ethane	0.4
Ethylene	8.7
Methane	8.5
Oxygen	0.5
Propylene	0.6
Water	0.9
Flowrate = 5,460 scfh	

[a] Reference 11.

ACETONE/PHENOL[8, 63, 117, 125]

Source of emissions: Manufacture of acetone/phenol from cumene peroxidation

Emissions: Acetone, cumene, phenol, acetaldehyde, α-methyl styrene, formaldehyde, ethylbenzene, toluene

Control Device/Practice	Comments	Control Efficiency (VOC)
Carbon adsorption	Cumene oxidation vent is controlled by carbon adsorption followed by refrigerated condensation.	92%[a], 99%[b] 83.4%[c]
Condenser	Cumene oxidation vent is controlled by a refrigerated condenser at 4-5°C and 85 psia.	90%
	Oxidate wash/separation vent is controlled by condensation.	84%
	Chilled-brine condensation is used to control the cumene hydroperoxide (CHP) vent.	
	CHP vent is controlled by condensation.	95%
	CHP cleavage vent is controlled by condensation.	93%
	CHP cleavage vent and CHP neutralization vent are controlled by refrigerated condensation followed by water scrubbing.	
	Light-ends column vent and acetone finishing column vent are controlled by refrigerated condensation followed by water scrubbing.	
	Condensers are used to control emissions from several other distillation column vents such as α-methyl styrene, phenol, acetophenone, crude acetone/phenol, heavy ends, and phenol purification columns.	
	Condensers are also used on acetone, light and heavy oil, cumene/CHP, and on crude by-product tanks to control storage emissions.	

CONTINUED

ACETONE/PHENOL (CONTINUED)

Control Device/Practice	Comments	Control Efficiency (VOC)
Scrubber	CHP neutralization vent is controlled by a water scrubber.	93%
	A water scrubber following a condenser is used to control emissions from CHP cleavage vent.	96%[d]
	Aqueous scrubbing is used to control light-ends column vent.	
	Aqueous scrubbing is used to control acetone finishing column vent and cleavage product storage tanks.	
Boiler	The vent stream from light-ends columns is incinerated by using it as fuel in existing boilers.	
	Distillation column vents (acetone, α-methyl styrene, etc.) are incinerated in fire boxes of existing boilers.	
Floating roof tank	Used for controlling storage emissions from acetone, cumene, and crude α-methyl styrene storage tanks.	
Process modifications	Excess oxygen in the spent air can be varied. This will directly affect the quantity of spent air and thus the VOC emission rate from the process vent.	
	Another variation that can greatly reduce the emissions from the main process vent is the use of oxygen instead of air in the oxidation step, thereby greatly reducing the inert-gas venting.	
	Another process variation is the hydrogenation of the crude α-methyl styrene stream to produce cumene for recycle rather than to produce an α-methyl styrene product for sale. This variation will reduce the emissions associated with α-methyl styrene production distillation and storage.	
Catalytic incinerator	Pilot studies at a phenol production facility were conducted at 675-825°F.	92-98%

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[a] Overall hydrocarbon removal efficiency.
[b] Overall removal efficiency.
[c] Efficiency for the carbon adsorption step calculated from design data.
[d] For scrubber only.

ACROLEIN[5, 11, 125]

Source of emissions: Production of acrolein by propylene oxidation

Emissions: Acrolein, propylene, acetaldehyde

Control Device/Practice	Comments
Flare	Flares are used to control emissions from various vents.
Thermal incinerator	Acrolein absorber vent is controlled by thermal oxidation.

ACRYLIC ACID[5, 11, 81, 125]

Source of emissions: Manufacture of acrylic acid from propylene oxidation

Emissions: Acrylic acid, acrolein, acetic acid, acetone

Control Device/Practice	Comments	Control Efficiency (VOC)
Condenser		
Scrubber	Vapor scrubbers are used on some tetrahydrofuran and acrylic acid tanks.	
Flare	Acrolein and acrylic acid streams are routed to a flare. Acrolein streams include acrolein distillation column vents, acrolein unit tank vents, and discharges from safety valves. Acrylic acid streams vented to the flare include acrylic acid extractor vent, the raffinate stripping column vent, and field acrolein tank safety valve discharges. Storage emissions are also controlled by flares.	
Catalytic incinerator	This device is used to control acrylic acid emissions during product handling.	
Thermal incinerator	Thermal oxidizers are used for controlling quench-absorber off-gas, atmospheric and vacuum equipment vents, storage, and handling emissions. Table B-7 presents the results of tests conducted at two plants.	See Table B-7
Conservation vent	Used for controlling storage emissions.	
Floating-roof tank	Used for controlling storage emissions.	
Vapor recovery	Used for controlling storage emissions.	
Blanket gas	Used for controlling storage emissions.	
Flare[a]	The absorber and reactor vent gas is fed to a flare. The composition of this stream is given in Table B-8.	99%

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[a] For Dow-Badische process.

TABLE B-7. THERMAL INCINERATION TEST DATA[a,b,c]

Production Rate During Test Waste Gas Flow (Inlet) scfm	Number Of Tests Or Sets	Supplemental Fuel & Amount Used (scfm)	Residence Time (Seconds)	Incineration Temperature (°F)	Inlet VOC (ppmv)	Outlet VOC (ppmv)	VOC Destruction Efficiency (wt %)
Each 52,500 (12,500 tank farm vent (TVF))	Set 1 3	900 (gas)	1.0	1425	TVF 2,580 OXV 11,600	1,330	82.6
	Set 2 4	900	1.0	1510	TVF 2,600 OXV 12,800	150	98.3
(40,000 oxidizer vent (OXV))	Set 3 1	900	1.0	1545	TVF 2,410 OXV 12,200	25	99.7
20,600	Set 1 6	Natural Gas	2-3	1160	11,900	243	96.1
	Set 2 3		2-3	1475	11,900	10	99.9

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[a] Reference 125

[b] The first set of data was taken at Rohm & Haas, Deer Park, TX.

[c] The second set of data was taken at Union Carbide, Taft, LA.

TABLE B-8. COMPOSITION DATA FOR WASTE STREAM FED TO A FLARE[a]

Compound	Composition (Wt. %)
CO	88.0
C_2H_2	8.0
C_2H_4	1.6
N_2	1.6
CO_2	0.8
Flowrate = 187 lb/hr	

[a] Dow-Badische, Freeport, TX. Reference 11.

ACRYLONITRILE[5, 11, 117, 125]

Source of emissions:Manufacture of acrylonitrile by ammoxidation of propylene

Emissions: Propylene, acrylonitrile, acetonitrile, hydrogen cyanide, propane

Control Device/Practice	Comments	Control Efficiency (VOC)
Scrubber	Scrubbers (water) are used for controlling emissions from column vents and storage tank vents. A control efficiency of 99% is reported for the scrubbers serving the storage tanks. In one plant, the scrubber vent is sent to a flare.	99%
Condenser	Condensers are used for controlling column and storage tank vents. Refrigerated condensers are used for storage tank vents.	
Catalytic incinerator	This device is used to control absorber vent emissions. The destruction efficiency is only 24% with respect to propane because this unit was not designed for propane.	24% (for propane)
Thermal incinerator	Emissions from absorber vents are controlled by thermal oxidizers. Test data obtained at Monsanto's manufacturing facilities show >99% removal efficiency. The waste gas flowrate during the tests was 75,000 lb/hr (average). The outlet VOC concentrations were 25 and 47 ppmv for the two tests.	
Flare	Flares are used for destroying emissions from column vents and storage tank vents. At one plant, emissions from the column vents are collected by the flare header system and controlled by a 16-inch flare designed for emergency and shutdown use. A separate 6-inch flare is used to control emissions from HCN storage tank. At another plant, the flare serves the header that collects vent gases from various vents. The stack consists of a 24-inch pipe extending 200 ft above ground.	

(CONTINUED)

ACRYLONITRILE[5, 11, 117, 125] (CONTINUED)

Control Device/Practice	Comments	Control Efficiency (VOC)
Nitrogen blanket	Used for controlling storage emissions from acrylonitrile and acetonitrile storage tanks.	
Carbon adsorber	Used for controlling storage emissions.	
Floating-roof tank	Used for controlling emissions from storage tank vents.	

ADIPIC ACID[7], 117

Source of emissions: Manufacture of adipic acid by oxidation of cyclohexanol/cyclohexanone with nitric acid

Emissions: Adipic acid, acetic acid, formic acid

Control Device/Practice	Comments	Control Efficiency (VOC)
Boiler	Off-gas from the absorber is routed to the powerhouse boilers designed to produce steam.	99%
Thermal incinerator	Off-gas from the absorber is routed to a thermal incinerator unit. This unit has no provision for heat recovery.	99+%
Scrubber	Wet scrubbers are used to control emissions from dryer and cooler vents.	
Fabric filter	Filter bags are used to control emissions from dryer and cooler vents.	
Carbon adsorber		

ALLYL ALCOHOL[11]

Source of emissions: Production of allyl alcohol from acrolein and sec-butanol (in glycerine manufacturing)

Emissions: Allyl alcohol, acrolein, acetone

Control Device/Practice	Comments
Flare	A flare is used to control emissions from lights stripper column vent.
Scrubber	Filtration system vent is controlled by a scrubber.
Condenser	Condensers are used for controlling emissions from catalyst preparation vent and distillation column vents.

ALLYL CHLORIDE[11]

Source of emissions: Production of allyl chloride by propylene chlorination (in glycerine manufacturing)

Emissions: Propylene, allyl chloride, chlorinated hydrocarbons, dichloropropane

Control Device/Practice	Comments
Condenser	A condenser is used to control emissions from light-ends distillation column vent.
Flare	Flares are used to control emissions from absorber and distillation vents.
Scrubber	A scrubber is used to control emissions from dichloropropane distillation column vent.

ANILINE[8, 117]

Source of emissions: Manufacture of aniline by vapor-phase hydrogenation of nitrobenzene

Emissions: Benzene

Control Device/Practice	Comments	Control Efficiency (VOC)
Condenser	Condensers are used to control emissions from distillation, catalyst filtration and recycle, and from storage.	96%
Scrubber	Water scrubbers are used to control process and storage emissions.	99.9%
	Dilute sulfuric acid scrubber is used as a control device.	
Thermal incinerator	Thermal incinerators are used to control reactor vent vent emissions and also for control of secondary emissions.	>99%[a]
Process variation	A process variation that can significantly influence process emissions is the manner in which the catalyst is handled. One producer reports filtration of catalyst fires from the reaction gases outside the reactor for recycle.	
Carbon adsorber		

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[a] Overall efficiency for process and secondary emission sources.

BUTADIENE[5, 11, 62, 125]

Source of emissions: Manufacture of butadiene by (a) dehydrogenation of n-butane, (b) oxidative dehydrogenation of n-butene, and (c) extraction from ethylene plant by-product streams

Emissions: Butadiene, isobutane, butene, isobutene, acetylenes

Control Device/Practice	Comments	Control Efficiency
Catalytic incinerator	Dehydrogenation reactor vent is controlled by catalytic incineration (dehydrogenation of n-butene). Data from one plant are presented in Table B-9.	92%[a], 50%[a]
Thermal incinerator	Reactor vent emissions are controlled by thermal incineration (n-butane dehydrogenation and n-butene oxidative dehydrogenation). Test results obtained at one plant are presented in Table B-10. Additional data for the same system are given in Table B-11.	
Flare	Purification column vents from all three processes are sent to flares.	
Boiler	Methyl and vinyl acetylenes, after being diluted with natural gas, are burned in a steam boiler as auxillary fuel.	
Recycle	Purification column vents are recycled to the ethylene plant (ethylene by-product extraction).	

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[a] Hydrocarbon removal efficiency.

TABLE B-9. DATA FOR CATALYTIC INCINERATOR[a]

	Houdry "Puff" Reactor
Waste Gas Flow, lb/hr	900,000 (total) 13,000 (Puff reactor)
Contaminants, wt. %	
Hydrocarbon	0.5
Carbon Monoxide	-
Removal Efficiency, %	
Hydrocarbon	92
Carbon Monoxide	-
Construction:	
Year	1975
Cost, $	725,000
Heat	
Efficiency, %	80
Natural Gas Added, Std.	
cu. ft./hr	0
Retention	
Time, Sec.	0.3

[a] Petro-Tex Chemical Corp., Houston, TX. Reference 62.

TABLE B-10. THERMAL INCINERATION TEST RESULTS[a]

Production Rate During Test Waste Gas Flow (Inlet) scfm	Number Of Tests Or Sets	Supplemental Fuel & Amount Used (scfm)	Residence Time (Seconds)	Incineration Temperature (°F)	Inlet VOC (ppmv)	Outlet VOC (ppmv)	VOC Destruction Efficiency (wt %)
		Natural Gas					
7,250	Set 1	1,400	0.6	1400	10,300	1,000	70.3
15,617	Set 2	1,467	0.6	1400	10,650	215	94.1
20,750	Set 3	900	0.6	1400	10,650	215	94.1
15,867	Set 4	1,175	0.6	1400	10,300	10	99.6
12,500	Set 5	1,176	0.6	1400	10,300	10	99.6
Avg. Combustion Air: 49,333							

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[a] Petro-Tex Chemical Corp., Houston, TX. Reference 125.

TABLE B-11. DATA FOR OXO-INCINERATOR SYSTEM[a]

	Oxo-Incinerator
Waste Gas Flow, lb/hr	235,000
Contaminants, wt. %	
Hydrocarbon	0.4
Carbon Monoxide	0.7
Removal Efficiency, %	
Hydrocarbon	93
Carbon Monoxide	95
Construction:	
Year	1976
Cost, $	2,500,000
Heat Efficiency, %	82
Natural Gas Added, Std. cu. ft./hr	130,000
Retention Time, Sec.	0.5

[a] Petro-Tex Chemical Corp., Houston, TX. Reference 62.

CADMIUM[73,77]

Control Device/Practice	Source of Emissions	Control Efficiency[a] (%)
ESP[b]	Fossil fuel combustion	99.6, 98.8, 93, 97.8, 99.3, 95.5, 91.2
Wet scrubbers[b]	Fossil fuel combustion	99, 77, 89
Physical coal cleaning[b]	Fossil fuel combustion	51.9[c], 49.5[d], 73.8[e], 44.7[f]
Wet scrubber (venturi)	Primary zinc smelting	99, 99.9, 99.9
Baghouse	Primary zinc smelting	
Hooding and enclosures	Primary zinc smelting	
Baghouse	Primary lead smelting	99, 99, 99, 99, 99, 99, 99
Wet scrubber	Primary lead smelting	98, 98
Baghouse/scrubber	Primary lead smelting	99
Hooding and enclosures	Primary lead smelting	
ESP	Primary copper smelting	19, 96.5, 96.7, 96.7, 96[b]
Multicyclones	Primary copper smelting	85
SCAP/DCAP[g]	Primary copper smelting	98.4, 99.3
Hooding and enclosures	Primary copper smelting	

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[a] Emission reduction is reported as total emissions unless otherwise noted.
[b] Efficiency reported for Cd emissions.
[c] Average Mn removal efficiency for 20 different coals.
[d] Average Mn removal efficiency for Eastern coals.
[e] Average Mn removal efficiency for Midwestern coals.
[f] Average Mn removal efficiency for Western coals.
[g] Single and double contact acid plants; the waste stream is treated for SO_2 removal but particulate emissions are also removed during this process.

CAPROLACTAM[5, 7]

Source of emissions: Manufacture of caprolactam from cyclohexanone

Emissions: Benzene, caprolactam

Control Device/Practice	Comment	Control Efficiency (VOC)
Condenser	A condenser is used for controlling emissions from cyclohexanone purification vents.	90%
	Condensers are used for controlling emissions from neutralization reactor vent, phase separation, solvent recovery and stripping vents.	70%, 90%
	The vents controlled by condensers contain benzene and other VOC.	
Scrubber and Thermal incinerator	Dehydrogenation reactor vent is controlled by a scrubber and a thermal incinerator.	
Fuel gas	Dehydrogenation reactor vent is used as fuel in one plant.	
Dust collector	This device is used for controlling emissions from caprolactam purification.	
Process modification	Using toluene as the solvent in place of benzene with the OSM/HPO (Stamicarbon) process results in elimination of benzene emissions.	
Catalytic incinerator		

CARBONTETRACHLORIDE AND PERCHLOROETHYLENE[9]

Source of emisions: Manufacture of carbon tetrachloride and perchloroethylene by hydrocarbon chlorinolysis

Emissions: Carbon tetrachloride, perchloroethylene

Control Device/Practice	Comments
Condenser	Refrigerated condensers are used to control emissions from carbon tetrachloride storage emissions.
Recycle	
Transfer to another process	
Pressurized N_2 padding	Used to control storage emissions of carbon tetrachloride and perchloroethylene.
Scrubber	Caustic scrubber is used for treatment of process emissions of carbon tetrachloride and perchlorethylene (the emissions are not from a chlorinolysis process). The VOC stripped from waste caustic is recycled to the process.
Vapor balance	

CHLOROMETHANES (METHYL CHLORIDE, METHYLENE CHLORIDE, CHLOROFORM, CARBON TETRACHLORIDE)[9, 60, 117]

Source of emissions: Manufacture of chloromethanes by (a) methanol hydrochlorination and methyl chloride chlorination, and (b) methane chlorination processes

Emissions: Methanol, methyl chloride, methylene chloride, chloroform, carbon tetrachloride

Control Device/Practice	Comments	Control Efficiency (VOC)
Condenser	Condensation is used to reduce inert-gas purge vent emissions.	50%
	River-water condensation system is used for control of emissions from light-ends columns and from product and raw material handling.	
	A similar system is used on storage tank vents, separation and purification area process vents.	
	Refrigerated vent condensers are used for control of storage emissions.	
Scrubber	A caustic scrubber is used to control chlorine and hydrogen chloride emissions.	
Flare	Emergency releases from process safety valves are controlled by a flare at a methyl chloride manufacturing facility.	
Carbon adsorber	Used for controlling storage emissions from methyl chloride, methylene chloride, and chloroform storage tanks.	
	This technique is also used to control methylene chloride emissions in combination with condensation from pharmaceutical manufacturing.	>90%[a]

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[a] Efficiency reported for emissions from pharmaceutical manufacturing.

CHLOROBENZENES[7, 117]

Source of emissions: Manufacture of chlorobenzenes by benzene chlorination

Emissions: Benzene, monochlorobenzene, dichlorobenzene

Control Device/Practice	Comments
Scrubber	Water and caustic scrubbers are used to control benzene and other VOC emissions. Venturi scrubbers are used for vents from distillation and vacuum systems. The emissions contain benzene, VOC, hydrogen chloride, and inerts.
Adsorber	Carbon adsorption is used for controlling p-dichlorobenzene emissions from crystallization and crystal processing.
Condenser	Vent condensers are used for distillations column vents and benzene storage vents.

CHLOROPRENE[11, 31, 62]

Source of emissions: Manufacture of chloroprene by butadiene chlorination and manufacture of neoprene by polymerization

Emissions: Butadiene, chloroprene, dichlorobutene

Control Device/Practice	Comments	Control Efficiency (VOC)
Scrubber	A caustic scrubber is used to control emissions from the chlorination vent.	
	An oil absorber is used to control emissions from chloroprene stripper and brine stripper vent.	100%
	Table B-12 presents data for two absorption systems.	
Condenser	Refrigerated condensers are used for controlling dichlorobutene, distillation, isomerization and distillation, chloroprene stripper, and storage tank vents.	93%, 94%
	Chloroprene fractionating column vents are controlled by brine cooling at 0°F.	92%[b]
	Brine cooling at 0°F is used for controlling chloroprene fractionating columns, isomerizer, and chlorprene condenser vent emissions.	50%[a], 94%[a] 95.6%[a]
	Brine cooling at 32°F is used for controlling emissions from batch polykettles.	68%[a]
	Brine cooling at 0°F is used for controlling emissions from neoprene strippers.	99.9%[a], 99.9%[a]
	Table B-13 presents data for five condensation systems.	

CONTINUED

CHLOROPRENE[11, 31, 62] (CONTINUED)

Control Device/Practice	Comments	Control Efficiency (VOC)
Condenser/Scrubber	A refrigerated condenser and a water scrubber are used in combination for controlling emissions from dichlorobutene distillation vent.	96.5%
	A refrigerated condenser and an oil scrubber are used in combination for controlling emissions from isomerization and distillation vents. Data for condenser/oil scrubber systems are tabulated in Tables B-12 and 13.	99.5%
Flare	Emissions from the butadiene dryer vent are sent to a flare.	100%

[a] Hydrocarbon removal efficiency.
[b] Combined removal efficiency (89% for water quenching and 28% for brine cooling).

TABLE B-12. ABSORPTION SYSTEMS[a,b]

	Neoprene Monomer Absorber	Neoprene Polymer Vent Absorber
Spray Tower Stages	2	5
Waste Gas Flow to ABS[c] Hydrocarbon, lb/hr	31	72
Waste Gas Flow, Total, lb/hr	36	187
Absorber Efficiency, %	90	97
Heat Load, Btu/hr	13,000	330,000[d]
Operating Temperature, °F	65	45
System Efficiency Including Condensation, %	99.5	98.4
Construction;		
Year	1975	1974
Cost, $	60,000	300,000

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[a] Petro-Tex Chemical Corp., Houston, TX. Reference 62.

[b] Absorption fluid is oil.

[c] Absorber.

[d] Includes heat load for recovery of hydrocarbons.

TABLE B-13. CONDENSATION SYSTEMS[a]

	Neoprene Monomer Isomerization Tower	Neoprene Monomer Topping Column[b]	Neoprene Polymer Vessel Vents[b]	Neoprene Latex Stripper Vent	Neoprene Polymer Emergency Dump System
Type of Heat Exchanger	S&T[c]	S&T[c]	DC[d]	S&T[c]	DC[d]
Waste Gas Flow, lb/hr Hydrocarbon	159	-	126	1,140	15,200 Hcb. Total
Waste Gas Flow, lb/hr Total	331	542	275	2,875	32,000 Total Dump
Hydrocarbon Removal Efficiency, %	81	99	43	99.8	99.995
Heat Load, Btu/hr	22,000	93,000	110,000	1.2 Million	10,000 Steady State; 3 Million Heat Sink/Dump
Operating Temperature, °F	-2	-2	36	-2	40 to 75
Construction:					
Year	1973	1973	1974	1969	1974
Cost, $	20,000	30,000	40,000	120,000	250,000

[a] Petro-Tex Chemical Corp., Houston, TX. Reference 62.

[b] Waste gas exiting this system is further treated in absorption system.

[c] Shell-and-Tube.

[d] Direct contact with water.

CHROMIUM[73,75]

Control Device/Practice	Source of Emissions	Control Efficiency[a] (%)
ESP	Coal and oil combustion	96.2, 99.8, 98.6, 99.8, 98.7, 97, 97.6, 99.2, 85.6
Fabric filter	Coal and oil combustion	99.8, 99.70, 99.94
Wet scrubber	Coal and oil combustion	96.1[b], 88.9[b], 95, 90[c], 97[d], 90
Physical coal cleaning	Coal and oil combustion	53.4[e], 65.2[f], 49.8[g], 27.3[h]
Fabric filter	Steel manufacturing	99.9
ESP	Steel manufacturing	
Wet scrubber	Steel manufacturing	

[a] In terms of Cr emissions.

[b] Venturi scrubber.

[c] Oil combustion.

[d] The scrubber is preceeded by an ESP.

[e] Average Mn removal efficiency for 20 different coals.

[f] Average Mn removal efficiency for Eastern coals.

[g] Average Mn removal efficiency for Midwestern coals.

[h] Average Mn removal efficiency for Western coals.

COKE OVEN EMISSIONS[12, 13, 14, 15, 16, 83, 92, 200, 103, 104, 105, 106]

Source of emissions: Coke oven by-product recovery plants

Control Device/Practice	Comments	Control Efficiency
ESP	A wet ESP has been used for controlling POM emissions from coke oven door leakage during coking cycle.	95.6%[a]
Staged charging	Used for controlling emissions during charging.	
Larry car mounted scrubbers	Used for controlling emissions during charging.	
Sequential charging	Used for controlling emissions during charging.	
Modified larry car design	Used for controlling emissions during charging.	
Oven/battery sheds	Used for controlling emissions during coking.	
Oven and door maintenance	Used for controlling emissions during coking.	
Improved operating procedures	Used for controlling emission during coking.	
Coke side sheds	Used for controlling emissions during pushing.	
Spray systems	Used for controlling emissions during pushing.	
Enclosed/hooded quench cars with mobile scrubber cars	Used for controlling emissions during pushing.	
Bench mounted hood-fixed duct	Used for controlling emissions during pushing.	
Traveling hood-fixed duct	Used for controlling emissions during pushing.	
Dry quenching	Used for controlling emissions during quenching.	
Pressure quenching	Used for controlling emissions during quenching.	
Two-step quenching	Used for controlling emissions during quenching.	

[a] Average efficiency for total POM excluding naphthalene.

COPPER[77]

Control Device/Practice	Source of Emissions	Control Efficiency[a] (%)
ESP (hot)	Primary copper smelting	19, 96.5, 96.7, 96.7
Spray chamber/ESP	Primary copper smelting	
Baghouse	Primary copper smelting	
CAP[b]	Primary copper smelting	98.4
Settling chamber	Primary copper smelting	
Cyclone	Primary copper smelting	85

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[a] Emission reduction is reported as total emissions unless otherwise noted.

[b] Off-gases transferred to sulfuric acid contact plant where particulate matter emissions are also controlled during SO_2 removal.

CUMENE[5, 8]

Source of emissions: Manufacture of cumene by alkylation of benzene with propylene (solid phosphoric acid or aluminum chloride catalyst)

Emissions: Benzene, cumene (catalyst: phosphoric acid),
Benzene, cumene, diisopropylbenzene (catalyst: aluminum chloride)

Control Device/Practice	Comments
Fuel gas	Vent streams are transferred to fuel gas manifold.
Flare	Benzene recovery system vent and cumene distillation column vent are burned in plant flares.
Condenser	Benzene recovery system vent is controlled by a condenser.
Floating-roof tank	Used for benzene storage emissions.
Catalytic incinerator	

CYCLOHEXANE[7, 117]

Source of emissions: Manufacture of cyclohexane from benzene hydrogenation and petroleum separation

Emissions: Cyclohexane, benzene

Control Device/Practice	Comments
Fuel gas	The off-gas containing hydrogen, methane, and cyclohexane is sent to a plant-wide fuel gas system.
Flare	Flares are used to control process or fugitive emissions. In one plant, smokeless flares are used for off-gases from column reboilers.
Floating-roof tanks	Used for controlling benzene and cyclohexane storage emissions.
Carbon adsorber	

CYCLOHEXANOL/CYCLOHEXANONE[7]

Source of emissions: Manufacture of cyclohexanol/cyclohexanone by (a) cyclohexane oxidation or (b) phenol hydrogenation

Emissions: Cyclohexane, cyclohexanol, cyclohexanone, benzene, phenol

Control Device/Practice	Comments
Source (a)	
Absorber	The high and low pressure absorbers are not regarded as control devices. They are considered as part of the process equipment.
Boiler	High-pressure scrubber off-gas is sent to a plant boiler.
Flare	Absorber off-gas is sent to a flare.
Source (b)	
Boiler	The off-gas from the process is sent to plant boilers.

EPICHLOROHYDRIN[11]

Source of emissions: Production of epichlorohydrin (in glycerine manufacturing)

Emissions: Epichlorohydrin, chlorinated hydrocarbons

Control Device/Practice	Comments
Scrubber	Scrubbers are used to control column vent emissions.
Thermal incinerator	Thermal oxidizers are used to control reactor and azeotrope column vents.
Practice	Use of sodium hydroxide or calcium hydroxide to neutralize the hydrochloric acid and close the epoxide ring reduces VOC emissions from the reactor vent.

ETHANOLAMINES[10]

Source of emissions: Manufacture of ethanolamines from ethylene oxide and ammonia

Emissions: Emissions from this process are reported to be small.

Control Device/Practice	Comments
-	-

ETHYLBENZENE/STYRENE[7]

Source of emissions: Manufacture of ethylbenzene from benzene and ethylene and styrene from ethylbenzene

Emissions: Ethylene, benzene, styrene, toluene, ethylbenzene

Control Device/Practice	Comments
Absorber[a]	Absorbers are used to control emissions from alkylation reactors.
Condenser[a]	Condensers are used to control emissions from column vents and storage tank vents.
Flare[a]	Flares are used to control emissions from alkylation reactor vent, column vents, emergency vents, and storage tank vents.
Boiler	Reactor off-gas is used as fuel in boilers.
Process heater[a]	Reactor off-gas and column vents are transferred to process heaters.
Conservation vent	Used for controlling storage tank emissions.
Floating-roof tank	Used for controlling storage tank emissions.

[a] Reported uncontrolled emissions are summarized in Table B-14.

TABLE B-14. COMPOSITION DATA FOR VARIOUS VENTS[a]

Component	Composition (Wt. %)	Control Device
Organics	2	Condenser[b]
Benzene	44	
C_1-C_5 hydrocarbons	27	
Inerts	27	
Methane + Ethane	58	Absorber[c]
Benzene	13	
CO_2	29	
Methane + Ethane	81	Flare[d]
Benzene	19	
Hydrogen chloride	Trace	
Hydrocarbons	45-50	Process heater[e]
Hydrogen chloride	45-55	

[a] Reference 7.

[b] Monsanto Co.

[c] Arco.

[d] Gulf Oil Corp.

[e] Dow Chemical, USA.

ETHYLENE[10]

Source of emissions: Manufacture of ethylene by pyrolysis process

Emissions: Ethylene, benzene

Control Device/Practice	Comments
Flare	Elevated and horizontal flares are used in controlling intermittent and lube-oil vent emissions. In some applications, steam-assisted elevated flares are used. Flares are also used to control storage emissions.
High efficiency seals	Used for reducing lube-oil vent emissions.
Floating-roof tanks	Used for reducing storage emissions.

ETHYLENE DICHLORIDE[5, 9, 117, 125]

Source of emissions: Manufacture of ethylene dichloride by direct chlorination and oxychlorination processes

Emissions: Ethylene dichloride, ethane, chlorinated hydrocarbons, ethylene

Control Device/Practice	Comments	Control Efficiency (VOC)
Thermal incinerator	Streams from oxychlorination and direct chlorination vents are burned in thermal incinerators. Compositions of waste streams controlled by incineration as reported by industry are shown in Table B-15.	
Post reactor	A device that reduces ethylene in the oxychlorination vent gases is a post reactor where chlorine is added to chlorinate the residual ethylene to ethylene dichloride. Reported uncontrolled emissions from plants using this technique are listed in Table B-16.	
Recycle	Purification vents are returned to process.	
Condenser	Direct-chlorination vents are controlled by refrigerated condensers. Composition of such a stream is given in Table B-17. Vent condensers are used also for purification vents.	
Scrubber	Water scrubbers are used for purification vents. Chilled water scrubbers are used for oxychlorination vents. Composition data from one plant are shown in Table B-18. Solvent absorption is used for oxychlorination vents. Composition data from one plant are shown in Table B-18.	
Catalytic oxidizer	A catalytic oxidizer is used for controlling oxychlorination vent emissions. Composition data are reported in Table B-19.	99.7%[a] <75%[b], <60%[c]

[a] Efficiency reported for (C_2H_4+CO).
[b] Efficiency reported for $C_2H_2Cl_2$.
[c] Efficiency reported for vinyl chloride monomer.

TABLE B-15. REPORTED UNCONTROLLED EMISSIONS FROM OXYCHLORINATION AND DIRECT CHLORINATION VENTS[a]

Oxychlorination Vent		Direct Chlorination Vent	
Compound	Composition (Wt. %)	Compound	Composition (Wt. %)
C_2H_4	26	$C_2H_2Cl_2$	5
Other VOC	3	C_2H_3Cl	5
CO_2	44	C_2H_4	44
CO	4	C_2H_6	2
N_2	15	CO_2	19
O_2	3	N_2	17
VOC Flowrate = 570 lb/hr		VOC Flowrate = 700 lb/hr	

[a] PPG, Lake Charles, LA. Reference 9.

TABLE B-16. REPORTED UNCONTROLLED EMISSIONS (CONTROLLED BY POST-REACTOR)[a]

Compound	Composition[b] (Wt. %)	Composition[b] (Wt. %)	Composition[c] (Wt. %)
$C_2H_2Cl_2$	4.6	0.75	0.93
C_2H_3Cl	2.1	1.00	1.09
C_2H_4	0.8	0.02	0.26
Other VOC	2.6	0.23	0.13
CO	1.2	1.00	0.97
C_2H_6			0.01
CH_4			0.09
CO_2			2.00
N_2			94.5
		VOC Flowrate = 1,040 lb/hr	VOC Flowrate = 1,085 lb/hr

[a] Reference 9.
[b] Shell, Deer Park, Texas.
[c] Conoco, Westlake, LA.

TABLE B-17. COMPOSITION OF WASTE STREAM FED TO A REFRIGERATED CONDENSER[a]

Compound	Composition (Mole %)
$C_2H_2Cl_2$	1.7
C_2H_3Cl	0.01
C_2H_4	3.3
Other VOC	0.02
C_2H_6	0.8
CH_4	15.1
CO_2	1.63
CO	1.1
N_2	42.8
O_2	14.5
H_2	4.4

[a] Conoco, Westlake, LA. Reference 9.

TABLE B-18. COMPOSITION DATA FOR WASTE STREAMS FED TO A WATER (CHILLED) SCRUBBER AND SOLVENT ABSORBER[a]

Compound	Composition[b] (Wt. %)	Composition[c] (Wt. %)
$C_2H_2Cl_2$	20.89	0.28
C_2H_3Cl	0.09	
C_2H_4	19.09	0.44
Other VOC	0.12	0.09
C_2H_6	40.75	0.15
CH_4		0.90
CO_2		2.85
CO	19.09	0.67
N_2		87.52
O_2		7.09
	VOC Flowrate = 504.3 lb/hr	VOC Flowrate = 1,880 lb/hr

[a] Reference 9.

[b] Water scrubber; Vulcan, Geismer, LA.

[c] Solvent absorber; B. F. Goodrich, Calvert City, KY.

TABLE B-19. COMPOSITION OF WASTE STREAM CONTROLLED BY CATALYTIC INCINERATION[a]

Compound	Composition (Wt. %)
$C_2H_2Cl_2$	0.39
C_2H_4	0.97
Other VOC	0.01
CO	1.29
VOC Flowrate = 260 lb/hr	

[a] Diamond Shamrock, Deer Park, TX. Reference 9.

ETHYLENE GLYCOL[10]

Source of emissions: Manufacture of ethylene glycol by addition of water to ethylene oxide.

Emissions: Ethylene oxide, acetaldehyde

Control Device/Practice	Comments
Condenser	Contact condensers are used to condense the vapors from the evaporator purge vents. Surface condensers are used for the same purpose as above. In some plants, heat is recovered from the surface condensers. An air-cooled condenser is also used for controlling evaporator vents.
Thermal oxidizer	Uncondensed gases from vent condensers are routed to a thermal oxidizer.
Flare	Uncondensed gases from vent condensers are routed to a flare.

ETHYLENE OXIDE[5, 10, 125]

Source of emissions: Manufacture of ethylene oxide by (a) air-oxidation or (b) oxygen-oxidation of ethylene

Emissions: Ethylene, ethylene oxide, ethane

Control Device/Practice	Comments
Source (a)	
Catalytic oxidation	
Recycle	
Scrubber	Used for controlling storage emissions
Flare	
Source (b)	
Alternate process	Waste stream is transferred to another process.
Utility boiler	Since the waste stream is high in ethylene, it is used as fuel in utility boilers. Table B-20 shows typical composition of a waste stream used as fuel. Table B-21 gives similar information for a stream which is burned in a utility boiler with flare alternate.
Flare	Used for controlling storage and process emissions.
Scrubber	Used for controlling storage emissions.
Recycle	

TABLE B-20. COMPOSITION OF WASTE GAS STREAMS USED AS UTILITY BOILER FUEL[a]

Component	Composition (Volume %)	
	Unit 1	Unit 2
O_2	4.1	5.5
C_2H_4	23.0	23.0
CH_4	47.0	51.0
CO_2	9.0	11.0
C_2H_6	0.1	0.1
N_2	9.0	3.7
Ar	7.0	4.8
H_2O	0.9	0.9
	Flow rate = 1,800 lb/hr	Flow rate = 650 lb/hr

[a] BASF Wyandotte Corporation, Geismar, LA. Reference 10.

TABLE B-21. COMPOSITION OF WASTE STREAM USED AS FUEL IN BOILER WITH FLARE ALTERNATE[a]

Component	Composition (Wt. %)
CO_2	11.7
C_2H_6	0.3
C_2H_4	29.4
CH_4	24.0
N_2	8.4
O_2	5.7
Ar	20.4

[a] Celanese Chemical Company, Pasadena, Texas. Reference 10.

FLUROCARBONS[9]

Trichlorofluoromethane F-11
Dichlorodifluoromethane F-12
Trichlorotrifluroethane F-113
Dichlorotetrafluoroethane F-114
Chlorodifluoromethane F-22

Source of emissions: Manufacture of fluorocarbons by catalytic reaction of anhydrous hydrogen fluoride and chlorinated hydrocarbons (carbon tetrachloride, chloroform, perchloroethylene)

Emissions: F-12, F-13, F-23, F-22, F-114, F-124, F-115

Control Device/Practice	Comments	Control Efficiency (VOC)
Condenser	A small purge condenser with -5°F brine coolant and a carbon tetrachloride scrubber is used to remove F-12 and F-13 from distillation vent. Composition data are given in Table B-22.	85.5%, 86.3[a], 99%[b], 83.5[c]
	A refrigerated condenser is used to recover F-22 from inerts and F-23 vented from the distillation column. Composition data are given in Table B-22.	75%[d], 25%
	A refrigerated condenser is used to recover F-23.	80%[e]
	A refrigerated condenser is used to recover F-22	76%[f]
Recycle	A refrigerated condenser using 1°F brine removes chloroform emissions from a chloroform storage tank.	66%[g]

[a] Efficiency in terms of fluorocarbon emissions.
[b] Efficiency based on F-12 only.
[c] For condenser at 0°F.
[d] Efficiency based on F-22 only.
[e] Efficiency based on F-23 and VOC.
[f] Efficiency based on F-22 and VOC.
[g] Efficiency in terms of chloroform emissions.

TABLE B-22. COMPOSITION DATA FOR WASTE STREAMS CONTROLLED BY REFRIGERATED CONDENSATION[a]

Compound	Composition (Wt. %)	Compound	Composition (Wt. %)
F-12	95.05	F-23	62.6
F-13	0.94	F-22	31.3
Inerts	4.01	Inerts	6.1

[a] Estimated from measured composition data on controlled emissions. Reference 9.

FORMALDEHYDE[5,10,125]

Source of emissions: Manufacture of formaldehyde from methanol by (a) silver and (b) metal oxide catalyst processes

Emissions: Formaldehyde, methanol, dimethyl ether, methylal, methyl formate

Control Device/Practice	Comments	Control Efficiency (VOC)
Source (a)		
Thermal oxidizer	Heat recovery from the incinerator flue gases is reported for one plant where a control efficiency of 100% is achieved. The temperature is 2000°F and the inlet concentration is 0.87 wt % VOC. Typical composition for the process emissions for this plant is given in Table B-23.	100%, 100%, 99.8%
Steam boiler	The emissions controlled by the steam boiler include VOC species such as methyl formate, methylal, and methanol.	100%, 100%
Flare		
Demister		
Condenser	Refrigerated water at 35°F is used to condense the emissions recovering methanol.	80%
	Refrigerated condenser	96.1%
	Condensers are also used to control methanol and formaldehyde emissions from storage tanks.	
Scrubber		
Conservation vent	Used for controlling storage tank emissions.	

FORMALDEHYDE (continued)

Control Device/Practice	Comments	Control Efficiency (VOC)
Source (b)		
Demister		
Scrubber	The performance of the water scrubber is hampered by the insoluble nature of the dimethyl ether contained in the vent stream from the absorber. Scrubbers are also used to control emissions from storage tanks for methanol and formaldehyde.	94%
Conservation vent	Used for controlling storage tank emissions.	

Table B-23. COMPOSITION OF PROCESS VENT EMISSIONS FED TO THE INCINERATORS[a]

Component	Composition (Wt%)
H_2	20.57
N_2 + air	74.03
CH_4	0.02
Methylal	0.19
Methyl formate	0.62
CH_3OH	0.06
CO_2	3.87
CO	0.64

[a] Celanese Chemical Plant, Bishop, Texas, Reference 10.

GLYCOL ETHERS[10]

Source of emissions: Manufacture of glycol ethers from ethylene oxide with primary alcohols

Emissions: Primary alcohols (Emissions from this process are estimated to be small.)

Control Device/Practice	Comments
-	Due to the low volatility of the products, the process emissions are small. Therefore, no emission control devices have been identified.

HEXACHLOROCYCLOPENTADIENE (HCCPD)[59]

Source of emissions: Waste water from manufacturing plants

Control Device/Practice	Comments
Wet air oxidation	This method is used to destroy HCCPD in waste water. Pilot test results showed greater than 90 percent reduction in HCCPD.

LINEAR ALKYLBENZENE (LAB)[8]

Source of emissions: Manufacture of LAB using paraffin chlorination or paraffin dehydrogenation process

Emissions: Benzene

Control Device/Practice	Comments
Process heater	Process vents are sent to heater for oxidation. Residual exhaust from column refining vents are also burned in process heaters.
Condenser	Surface condensers are used to condense jet exhaust.
	Refrigerated vent condensers are used to control benzene emissions from storage tanks.
	Vent condensers are used to minimize VOC to vacuum jets.
	A surface aftercondenser is proposed for controlling emissions from column vents.
Flare	Vent gases are sent to flare for combustion.
Oil/Water separator	Benzene in the aqueous acid stream from the HCl absorber is removed from the acid by an oil-water separator and activated carbon.
Absorber	A paraffin absorber is proposed for controlling process vents.
	A spray tower is proposed for controlling emissions from HCl absorber.

MALEIC ANHYDRIDE[5, 7, 62, 117 125,]

Source of emissions: Manufacture of maleic anhydride from benzene oxidation

Emissions: Benzene, maleic anhydride, xylene, formaldehyde, formic acid

Control Device/Practice	Comments	Control Efficiency (VOC)
Adsorber	A carbon adsorption system is used to recover benzene from the secondary-product recovery absorber. The vapor flow rate is 43,000 cfm at 100°F.	85% (range 65 -95%)
Scrubber	Scrubbers are used for emissions from product recovery absorber, vacuum system vents, storage tank vents, and flaking-pelletizing processes.	
Catalytic incineration		
Thermal incineration	Test data at two different manufacturing locations are presented in Table B-24. Typical composition data provided by one plant are shown in Table B-25. Data for thermal incinerator at another plant are presented in Table B-26.	
Floating-roof tanks	Used for controlling storage emissions.	
Conservation vents	Used for controlling storage emissions	
Return vent	Used for controlling storage emissions	
Process modification	The manufacture of maleic anhydride by butane oxidation process will result in no benzene emissions.	

TABLE B-24. THERMAL INCINERATION TEST RESULTS[a,b,c]

Production Rate During Test Waste Gas Flow (Inlet) scfm	Number Of Tests Or Sets	Supplemental Fuel & Amount Used (scfm)	Residence Time (Seconds)	Incineration Temperature (°F)	Inlet VOC (ppmv)	Outlet VOC (ppmv)	VOC Destruction Efficiency By Weight
33,000 (70% total capacity)	3	1,060 (gas)	0.6	1400	950	13	98.5
		1,060	0.6	1400	950	13	98.5
		1,060	0.6	1400	950	13	98.5
33,200 Air: 8,000	Set 1	Natural Gas	0.6	"Below 2000"	834	7	98.96
24,200 Air: 2,000	Set 2		0.6		834	8	98.96

[a] Reference 125.

[b] The first set of data was obtained at Denka, Houston, TX.

[c] The second set of data was obtained at Koppers Co. Inc., Bridgeville, PA.

TABLE B-25. TYPICAL COMPOSITION OF WASTE GAS FED TO THE INCINERATOR[a]

Compound	Composition (Wt. %)
C_6H_6	0.26
CO	2.08
O_2	16.15
H_2O	4.70
N_2	76.81
Flowrate = 136,838 lb/hr	

[a] Koppers Co., Inc., Bridgeville, Pennsylvania. Reference 7.

TABLE B-26. DATA FOR MALEIC INCINERATOR[a]

	Maleic Incinerator
Waste Gas Flow, lb/hr	220,000
Contaminants, wt. %:	
Hydrocarbon	0.25
Carbon Monoxide	1.8
Removal Efficiency, %	
Hydrocarbon	93
Carbon Monoxide	95
Construction:	
Year	1975
Cost, $	1,750,000
Heat Efficiency, %	85
Natural Gas Added, Std. cu. ft./hr	80,000
Retention Time, Sec.	0.7

[a] Petro-Tex Chemical Corp., Houston, TX. Reference 62.

MANGANESE[49,73]

Control Device/Practice	Source of Emissions	Control Efficiency[a] (%)
Wet scrubber	Iron and steel foundries	99+
Fabric filter	Iron and steel foundries	99
Wet scrubber (venturi)	Ferroalloy production	90+
Fabric filter	Ferroalloy production	98
Fabric filter	Dry cell battery production	98
ESP[b]	Fossil fuel combustion	94.2, 99.1, 100, 94.4, 66.0, 98.2, 99.3, 98.6, 98.4
Fabric filter[b]	Fossil fuel combustion	99.94, 99.78
Physical coal cleaning[b]	Fossil fuel combustion	65.1[c], 79.1[d], 72.8[e], 26.7[f]
Wet scrubber[b]		60, 80, 98, 87, 79

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[a] Emission reduction is reported as total emissions unless otherwise noted.
[b] Efficiency reported for Mn emissions.
[c] Average Mn removal efficiency for 20 different coals.
[d] Average Mn removal efficiency for Eastern coals.
[e] Average Mn removal efficiency for Midwestern coals.
[f] Average Mn removal efficiency for Western coals.

METHANOL[10]

Source of emissions: Manufacture of methanol from natural gas by steam reforming

Emissions: Methanol, methyl formate, methylal, dimethyl ether

Control Device/Practice	Comments
Supplementary fuel	Since the purge gas vent contains a large proportion of methane, hydrogen, and carbon monoxide, it is burned as fuel in the reformer or boiler. Typical compositions are given in Tables B-27 and 28.
Flare	A flare is used when the purge gas cannot be used as fuel.
Scrubber	Aqueous scrubbers are used for controlling methanol emissions from storage tanks. The scrubber effluent is sent to crude methanol tanks recovering the methanol scrubbed from the vent gases.
Alternate process	Purge gas is transferred to another process, thus, eliminating the emissions.
Floating-roof tanks	Used for controlling storage tank emissions.

Table B-27. COMPOSITION OF WASTE STREAM BURNED AS FUEL IN THE REFORMER[a]

Component	Composition (Wt %)
H_2	36.0
CO	35.0
CO_2	15.0
CH_4	10.5
N_2	3.0
CH_3OH, H_2O, dimethyl ether	0.5

Flowrate = 15,000 lb/hr

Temperature = 100 - 120°F

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[a] Du Pont, Beaumont, Texas, Reference 10.

Table B-28. COMPOSITION OF WASTE STREAM BURNED AS FUEL IN THE REFORMER[a]

Component	Composition (Wt %)
Dimethyl ether	62
Methanol	37
Methylal, acetone, methyl formate	1

Flowrate = 5,850 lb/hr

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[a] DuPont, Beaumont, Texas, Reference 10.

METHYL ETHYL KETONE (MEK)[11, 117]

Source of emissions: Manufacture of MEK by butanol dehydrogenation

Emissions: Sec-butyl alcohol (SBA)

Control Device/Practice	Comments
Flare	A smokeless flare is used as an emission control device.
	Vent gases from SBA recovery column and MEK dehydration column are routed to smokeless flares.
Scrubber	A water scrubber consisting of two parallel, vertical blowdown drums with internal horizontal baffles and countercurrent water flow is used to control VOC emissions from condenser vents and other sources.
Carbon adsorber	Used for controlling storage emissions.

METHYL METHACRYLATE[11, 117]

Source of emissions: Manufacture of methyl methacrylate using acetone cyanohydrin

Emissions: Methanol, acetone, hydrogen cyanide, methyl methacrylate, acetone, methyl formate

Control Device/Practice	Comments
Condenser	Emissions of acetone and hydrogen cyanide from the acetone cyanohydrin reactor are controlled by a condenser.
	Condensers are used to reduce acetone loss from the product distillation and recovery columns.
	Distillation columns in methyl methacrylate process are controlled by condensers.
Flare	Emissions from acetone cyanohydrin and hydrolysis reactors are controlled by flares.
Thermal incinerator	Purification and recovery column vents are sent to an incinerator after the condensers.
Carbon adsorber	Used for controlling storage emissions.

NICKEL[73,74]

Control Device/Practice	Source of Emissions	Control Efficiency[a] (%)
Cyclone/scrubber	Primary nickel smelting	
Fabric filter	Primary nickel smelting	
ESP	Primary nickel smelting	
Fabric filter	Nickel matte refining	99.5, 97, 99, 97, 97, 99, 99.8, 99
Cyclone/magnetic filter	Nickel matte refining	97
Fabric filter	Secondary metals recovery	
Wet scrubber	Secondary metals recovery	
ESP	Secondary metals recovery	
Cyclone	Secondary metals recovery	
Vacuum smelting	Secondary metals recovery	
Fabric filter	Ferrous metals production	
ESP	Ferrous metals production	100
Multicyclones	Cement production	100
ESP	Cement production	95
ESP/cyclone	Cement production	97.5
Fabric filter	Cement production	99.8
ESP[b]	Coal and oil combustion	96.3, 99.4, 99.7, 98, 96.4, 98.7, 78.5, 99.8
Fabric filter[b]	Coal and oil combustion	99.5, 100
Wet scrubber[b]	Coal and oil combustion	95[c], 90.8-98[d], 95, 83, >97[e], 97
Physical coal cleaning	Coal and oil combustion	40.6[f], 49,7[g], 50.7[h], 12.5[i]

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[a] In terms of total emission reduction unless otherwise noted.
[b] In terms of Ni emission reduction.
[c] Venturi scrubber.
[d] Horizontal scrubber.
[e] The Scrubber is preceded by an ESP.
[f] Average Ni removal efficiency for 20 different coals.
[g] Average Ni removal for Eastern coals.
[h] Average Ni removal efficiency for Midwestern Coals.
[i] Average Ni removal efficiency for Western coals.

NITROBENZENE[8]

Source of emissions: Manufacture of nitrobenzene by nitration of benzene

Emissions: Benzene, nitrobenzene

Control Device/Practice	Comments	Control Efficiency
Scrubber	A water scrubber is used to control benzene contaminated vent emission.	
Absorber	An absorption column where nitrobenzene is used as the scrubbing liquor is used to control all process emissions.	
	An absorption column that removes benzene by nitration in a circulation mixture of nitric and sulfuric acid has been reported. However, because of operating difficulties, the system has been converted to one using nitrobenzene.	>99% (design efficiency for benzene removal)
Condenser	Streams of oxides of nitrogen contaminated with benzene are controlled by condensation.	
	A refrigerated vapor condenser is used for control of benzene emissions from waste-acid tanks.	
Incinerator	Streams of oxides of nitrogen contaminated with benzene are incinerated.	
Floating-roof tank	Benzene storage emissions are controlled by using floating roof tanks.	

PERCHLOROETHYLENE/TRICHLOROETHYLENE[9]

Source of Emissions: Manufacture of perchloroethylene/trichloroethylene by (a) chlorination and (b) oxychlorination processes using ethylene dichloride

Emissions: Ethylene dichloride, chlorinated hydrocarbons, perchloroethylene, trichloroethylene

Control Device/Practice	Comments	Control Efficiency (VOC)
Source (a)		
Condenser	A chilled water condenser is used to control emissions from a drying column. Composition data from this plant are given in Table B-29.	80%
	A refrigerated condenser on distillation columns is used to control emissions. Vent gases from the condenser are sent to another process.	80%
	Refrigerated vent condensers are used to control emissions from storage tanks.	50-99%, 85%
Scrubber	Water scrubbers are used to control emissions from process vents. Composition data are shown in Table B-30.	
Source (b)		
Thermal oxidizer	A thermal oxidizer is used to burn emissions from vents. The incinerator temperature is 1425°F and the residence time is 0.4 seconds in the combustion chamber. Composition data for one plant are given in Table B-31..	>99%
Scrubber	Water scrubbers are used to control emissions from distillation column vents and product neutralizer vents.	

TABLE B-29. ESTIMATED COMPOSITION DATA FOR WASTE STREAM CONTROLLED BY CHILLED-WATER CONDENSER[a]

Component	Composition (Wt %)
Ethylene dichloride	30.5
Vinylidene chloride	25.1
trans-Dichloroethylene	10.9
cis-Dichloroethylene	2.91
Carbon tetrachloride	0.64
Trichloroethylene	1.08
Perchloroethylene	4.99
Total VOC	76
Water	0.02
Air	24
Total	100

[a] Diamond Shamrock, Deer Park, Texas. Reference 9.

TABLE B-30. ESTIMATED COMPOSITION DATA FOR WASTE STREAM CONTROLLED BY SCRUBBING[a]

Component	Composition (Wt %)
trans-Dichloroethylene	39
cis-Dichloroethylene	11
Vinylidene chloride	17
Perchloroethylene	13
Trichloroethylene	13
Other chlorinated C_2's	2
Total VOC	95
Nitrogen	5
Total	100

[a] PPG Industries, Lake Charles, LA. Reference 9.

TABLE B-31. ESTIMATED COMPOSITION DATA FOR WASTE STREAM CONTROLLED BY THERMAL OXIDATION[a]

Component	Composition (Wt. %)
trans-Dichloroethylene	26.0
Vinyl chloride	21.0
Vinylidene chloride	16.0
Perchloroethylene/trichloroethylene	0.3
Other chlorinated C_2's	24.7
Total VOC	88.0
Nitrogen	12.0
Total	100

[a] PPG Industries, Lake Charles, LA. Reference 9.

PHTHALIC ANHYDRIDE[97, 131, 145]

Source of emissions: Manufacture of phthalic anhydride by (a) o-xylene, or (b) napthalene process

Emissions: Phthalic anhydride, maleic anhydride, naphthaquinone, benzoic acid

Control Device/Practice	Comments	Control Efficiency
Source (a)		
Thermal incinerator	Main process vent gas is controlled by thermal incineration at 1400°F. A waste heat boiler recovers heat from the flue gases.	97%[a], 99.5%[b]
	Incineration of waste gas at 1200°F with heat recovery is practiced at another plant.	90%[a]
	An oil-fired thermal incinerator is used to incinerate the effluent from the scrubber and the light and heavy ends from the product purification columns. Temperature in the incinerator is 1700°F.	96%[a]
Source (b)		
Catalytic incinerator	A catalytic incinerator is used to control emissions from phthalic anhydride manufacturing process using naphthalene feedstock. The temperature of the incinerator is 800-1000°F.	42-60%[a]

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[a] Destruction of organics.
[b] Efficiency reported for CO.

POLYCHLORINATED BIPHENYLS (PCB'S)[38, 51, 68, 108, 109, 110, 126]

Source of emissions: Waste incineration

Control Device/Practice	Comments
Carbon adsorber	During pilot studies, carbon adsorption was used to remove PCB's from transformer oil.
Thermal incinerator	Thermal incineration has been used widely for destroying PCB's in wastes. All materials with PCB concentrations greater than 500 ppm must be incinerated under EPA prescribed conditions. For lower PCB concentrations (50-500 ppm), incineration in a high-efficiency boiler is also acceptable. During test runs on PCB contaminated waste oil, burned with pulverized coal in a boiler, an efficiency of 99.99999 percent is reported. In another commercial facility, during trial runs, PCB destruction efficiencies of 99.9998 and 99.99999 percent were obtained.
Landfilling	Landfilling is an acceptable method for disposal of wastes containing low PCB concentrations.

PROPYLENE OXIDE[11]

Source of emissions: Manufacture of propylene oxide by (a) chlorohydrination, (b) isobutane hydroperoxide, and (c) ethylbenzene hydroperoxide route

Emissions: Propylene oxide, t-butyl alchol (TBA), acetone, isobutane, methanol, aldehydes, isobutylene, propylene glycol, dichloroproane, dichloroisopropyl ether

Control Device/Practice	Comments
Source (a)	
Scrubber	Aqueous scrubbers (packed column) are used to control emissions from various columns and storage tanks.
Source (b)	
Scrubber	A caustic scrubber is used to remove carbonyl compounds from the reactor vent.
	Another scrubber using cool TBA is used to absorb the organic vapors from this stream.
Flare	Oxidation reaction vent containing TBA and butane are controlled by a flare.
	Flares are also used to control emissions from several column vents. The pollutants controlled include TBA, propylene oxide, acetone, isobutane, and isobutylene.
Source (c)	
Scrubber	Oil and water scrubbers are used to control emissions of ethylbenzene and other VOC and also to recover products from the oxidation reactor vent.
Flare	Waste stream containing ethylbenzene and styrene are burned in a flare.
Fuel gas	Waste stream containing TBA and other hydrocarbons are sent to plant fuel-gas mainfold.

TEREPHTHALIC ACID (TPA) AND DIMETHYL TEREPHTHALATE (DMT)[8, 117]

Source of emissions:
- a) Manufacture of crude TPA by air oxidation of p-xylene,
- b) Manufacture of crude DMT by methanol esterfication,
- c) Manufacture of purified TPA by hydrogenation and crystallization,
- d) TPA/DMT manufacture using Hercules-Imhauser-Witten process.

Emissions:
- a) P-xylene, acetic acid, methyl acetate, TPA (particulate),
- b) Methanol, DMT (particulate),
- c) TPA (emitted as vapor but sublimes on contact with atmosphere).

Control Device/Practice	Comments	Control Efficiency (VOC)
Source (a)		
Scrubber	Aqueous absorbers are used to control crystallization, separation, drying, distillation and recovery vents. Acetic acid storage vents are also controlled by water scrubbers. Pollutants controlled by scrubbers include methyl acetate, p-xylene, methanol, acetaldehyde, and acetic acid.	
Fabric filter	Particulate removal device is used to control TPA emissions.	
Conservation vent	Used for controlling p-xylene storage tank emissions.	
Floating roof tank		
Carbon adsorber	A small side stream from the reactor vent is passed through an adsorber for organic removal.	
Thermal incineration	Inorganic portions of the catalyst, byproducts and residues from the reaction and distillation columns and the unrecoverable portions of the product are disposed of in a rotary kiln incinerator. This stream contains acetic acid.	
Source (b) and (c)		
Scrubber	Water and hydrocarbon scrubbers are used to control reactor sludge transfer vents. Particulate pollutants are controlled by water scrubbers at two plants. A xylene absorber and hydrocarbon scrubbers are used to control crude DMT tank vents. A xylene absorber is used to control DMT and methanol emissions.	

(CONTINUED)

TEREPHTHALIC ACID (TPA) AND DIMETHYL TEREPHTHALATE (DMT) (CONTINUED)

Control Device/Practice	Comments	Control Efficiency (VOC)
	Water absorbers are used for controlling methanol storage emissions.	
	Methanol absorbers and hydrocarbon scrubbers are used for controlling DMT storage emissions.	
	Hydrocarbon scrubbers and vent condensers are used for controlling slurry mix tank vent emissions.	
Supplementary fuel	Methanol recovery still and low-boiler still vents are burned as fuel in a boiler.	
Conservation vent	Used for methanol, p-xylene, methyl p-toluate and benzoate (MPTB), and methyl p-formyl benzoate (MFB) storage emissions. Also used for slurry mix tank vent emissions.	
Floating-roof tank	Used for controlling methanol storage emissions.	
Fabric filter	Used for controlling MPTB and MFB emissions.	
Source (d)		
Carbon adsorber	Used for controlling p-xylene and light VOC from the off-gas.	97%[a], 80%
Absorber	Chilled solvent scrubber is used for methanol recovery.	99%
Thermal oxidizer	Acetic acid, formic acid, formaldehyde, and methanol emissions are controlled by burning the liquid wastes in an incinerator. Heat is recovered from the flue gases.	~100%
Condenser	Used to control p-xylene emissions from xylene-water decanter.	
Scrubber	Xylene vent scrubber is used to control aromatic methyl ester and xylene emissions.	97%
Fabric filter	Used to control DMT particulate emissions	99%[a]

[a] Efficiency for xylene removal.

[b] Efficiency for DMT removal.

TOLUENE DIISOCYANATE (TDI)[8, 117]

Source of emissions: Manufacture of toluene diisocyanate by phosgenation of primary amines

Emissions: Phosgene, dichlorobenzene, nitroaromatic compounds, organic amines, chlorinated hydrocarbons

Control Device/Practice	Comments	Control Efficiency (VOC)[a]
Scrubber	Water scrubbers (spray tower) designed to remove H_2SO_4 also remove VOC because of the nature of the nitro-aromatic compounds being scrubbed. The composition of a typical uncontrolled stream as determined from controlled composition and efficiency data are tabulated in Table B-32.	60%
	A wet venturi scrubber is used to remove H_2SO_4 and VOC including nitro-aromatic compounds.	60%
	A dilute caustic scrubber or hydrolysis column is used for phosgene removal. Dichlorobenzene is also present in the waste stream.	99%
	Packed water scrubber (hydrolysis column) is used for phosgene removal.	98%
	A wet venturi scrubber is used for particulate removal from the catalyst filtration unit (crude toluene diamine).	80%
Condenser	Water-cooled surface condensers are used for removal of organic amines or chlorinated hydrocarbons.	
Incinerator	A liquid incinerator is used to burn the lights from toluene diamine vacuum distillation columns.	
Process modification	A TDI process developed in Japan is based on dinitrotoluene carbonylation. The phosgenation step is absent in this process.	
Carbon adsorber		

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[a] Estimated control efficiencies based on plant data.

TABLE B-32. TYPICAL COMPOSITION FOR A VENT STREAM FED TO A WATER SCRUBBER[a]

Compound	Composition (Wt. %)
Combustion products + H_2O	99.68
SO_2	0.005
NO_x	0.06
H_2SO_4	0.18
Nitroaromatics	0.075

[a] Reference 8 .

1,1,1-TRICHLOROETHANE (METHYL CHLOROFORM)[9]

Source of emissions: Manufacture of 1,1,1-trichloroethane from vinyl chloride and ethane

Emissions: Vinyl chloride, ethylene dichloride, 1,1,1-trichloroethane

Control Device/Practice	Comments	Control Efficiency (VOC)
Scrubber	Water scrubbing is employed to control process emissions	90%
	Refrigerated absorption systems are used to control storage emissions.	
Recycle	Emissions are recycled to ethylene dichloride process.	
Glycol pots		
Condenser	Refrigerated condensers are used for controlling storage emissions.	
Thermal incinerator		

VINYL ACETATE[10]

Source of emissions: Manufacture of vinyl acetate from ethylene vapor-phase process

Emissions: Ethylene, vinyl acetate, acetic acid, acetaldehyde, ethane

Control Device/Practice	Comments	Control Efficiency (VOC)
Thermal oxidizer	Emissions from the CO_2 purge vent are controlled by thermal oxidizers. Composition data from one plant are shown in Table B-33.	
Catalytic oxidizer	Ethylene and ethane emissions from the CO_2 purge vent are controlled by a catalytic oxidizer.	97.5%
Flare	Inert-gas purge vent, emergency vent, and light ends vent are controlled by flares. The emissions consist of ethylene, ethane, vinyl acetate, acetic acid, ethane, and acetaldehyde. Composition data from one plant are shown in Table B-33.	100%, 100%

TABLE B-33. COMPOSITION OF WASTE STREAMS CONTROLLED BY A FLARE AND THERMAL OXIDIZER[a]

Flare		Thermal Oxidizer	
Compound	Composition (Wt. %)	Compound	Composition (Wt. %)
Ethylene	45	Ethylene	0.3
Vinyl acetate	10	CO_2	99.7
Acetic acid	2.5		
Other VOC	2.5		
Inerts	40		
Flowrate = 1,100 lb/hr		Flowrate = 600 lb/hr	

[a] Du Pont, Inc., La Port, Texas. Reference 10.

VINYLIDENE CHLORIDE[9, 117]

Source of emissions: Manufacture of vinylidene chloride by dehydrochlorination of 1,1,2-trichloroethane

Emissions: Vinylidene chloride, 1,1,2-trichloroethane, monochloroacetylene

Control Device/Practice	Comments	Control Efficiency (VOC)
Thermal incinerator	Emissions from the reactor vent are controlled by incineration.	98%
Condenser	Reactor vent emissions are controlled by a refrigerated condenser.	93%
	Storage emissions are controlled by refrigerated . condensers .	
Scrubber	Distillation vent emissions are controlled by a water scrubber.	90%
Recycle	At one plant, it is planned to use recycle for distillation vent control (will be eventually incinerated).	

ZINC[77,84]

Control Device/Practice	Source of Emissions	Control Efficiency[a] (%)
Cyclone	Primary zinc smelting	
ESP	Primary zinc smelting	
Wet scrubber (venturi)	Primary zinc smelting	
Fabric filter	Primary zinc smelting	
Baghouse	Secondary zinc smelting	
Afterburner/baghouse	Secondary zinc smelting	99.24
Hooding system	Secondary zinc smelting	
ESP (hot)	Primary copper smelting	
Spray chamber/ESP	Primary copper smelting	

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[a] Emission reduction is reported as total emissions.